ne theory and practice of programmed nstruction

by jerry pocztar

monographs on education

unesco

2832

MONOGRAPHS ON EDUCATION VII

Titles in this series:

- I. *Adult education in Yugoslavia*, by M. David.
- II. *The primary school curriculum*, by Robert Dottrens.
- III. *Polytechnical education in the U.S.S.R.*, edited by S. G. Shapovalenko.
- IV. *New trends in adult education: from Elsinore to Montreal*, by A. S. M. Hely.
- V. *The psychology of the use of audio-visual aids in primary education*, by G. Mialaret.
- VI. *Vocational and technical education*, by Hugh Warren.
- VII. *The theory and practice of programmed instruction: a guide for teachers* by Jerry Pocztar.

/c

THE THEORY AND PRACTICE OF PROGRAMMED INSTRUCTION

A guide for teachers

by Jerry POCZTAR

UNESCO PARIS
1972

S.C.E.R.T., West Bengal
Library
Calcutta
25/3, B. C. Road

Published in 1972
by the United Nations Educational, Scientific
and Cultural Organization,
Place de Fontenoy, 75 Paris-7e, France
Printed by
Imprimerie Polychrome, Paris

371.3
UNE

A[illegible] 2832

S.C.E.R.T.. West Bengal
Date... 25. 2. 82
Acc. No.... 2832

© Unesco 1972
Printed in France
ED.70/XVI.7/A

PREFACE

For a number of years, Unesco has endeavoured to assist Member States in perfecting teaching techniques and materials on a broader scientific basis, making particular use of the contributions of the psychology of learning.

The continuing nature of this endeavour is demonstrated by the series of Unesco-organized regional meetings and training seminars devoted to new methods and techniques. Most recently two experimental regional projects were launched to develop the applications of programmed instruction in the reform of school curricula. One of these projects is being carried out in four French-speaking Central African countries, following a meeting of experts in Brazzaville (July 1969), and the other in Asia, following a preparatory meeting in Tokyo (February 1970). Prior to the initiation of these projects, a meeting of experts, which took place at Varna (Bulgaria) from 19 to 29 August 1968, pointed to the need for an assessment of the theory and practice of programmed instruction in the form of a book directed specifically to teachers and teacher educators.

To prepare this book Unesco called upon Jerry Pocztar, Agrégé de l'Université, *who is in charge of programmed instruction at the Educational Research and Training Centre, École Normale Supérieure de Saint-Cloud (France) and who directed the 1969 Brazzaville training seminar referred to above.*

The book is intended as a guide for teachers who wish to acquaint themselves with programmed instruction; but it is also designed for those administrators or teacher-educators who will be involved in the development and promotion of this method of teaching. Of these readers, not all will need the same information. Administrators, for example, can acquire a good idea of what is involved in a trial scheme of programmed instruction in a school, and can help to ensure its success, without knowing particular psychological concepts. For the benefit of readers who wish to pursue this initial acquaintance further, references have been listed at the end of each chapter indicating supplementary reading. A short general bibliography at the end of the book lists major works which can help teachers to pass on an understanding of programmed instruction to their colleagues.

It is argued in the ensuing chapters that it is only through the practice of programmed instruction that the theoretical study of the subject can assume its real meaning. It is hoped that this guide may enable teacher-educators to lead teachers to the practice of programmed instruction, as a first step towards a scientific renewal of teaching methods.

It should be added that, consistent with the principles it expounds, this book will not be fulfilling its purpose unless it provokes feedback. From this first contact between teachers and Unesco's fund of experience should come a stream of exchanges which could be reflected in the Organization's future programme.

CONTENTS

Introduction 9

Chapter I. *From psychology to programmed instruction* . . 25
  From experimental psychology to behaviourist psychology 26
    Pavlov and the conditioned reflex 28
    From Thorndike to Watson: the arrival of the 'black box' 31
    Pressey's contribution 35
    Skinner 36
    The application of Skinner's psychological theories to teaching 43
  Conclusions 48

Chapter II. *Types or models of programmed courses* . . 51
  The Skinner programme 52
  The type of programme devised by Crowder . . 62
  Skip-branching 73
  Conclusions 75

Chapter III. *Techniques for elaborating programmed courses* . 76
  Introduction 76
  Section 1. The 'traditional' techniques . . . 79
    Defining the objectives 80
    Pre- and post-tests 93
    Organizing the subject-matter 100
    Constructing the flow-chart or Mechner 'tree' . 122
    Experimental testing: assessment and validation . 125
  Section 2. The new techniques 135
    Suppes 135
    The Soviet school 137
  Conclusions 148

Chapter IV. *Programmed instruction in class and school* . . 152
The organization of teaching 153
The curriculum 153
Class-room methods 158
Conclusions 169
Material organization 170
Aids and devices 170
Preparation for team-work 172

Conclusions 174

Further reading 177

INTRODUCTION

The year 1954 saw the field of educational methods and techniques enriched by the advent of programmed instruction. From the moment it was introduced by the American psychologist B. F. Skinner, programmed instruction achieved great success and made rapid progress: large sums were made available to experiment with it and put it into practice; the industrial and commercial press publicized the advances and setbacks of this new method of teaching; and research workers and educationists alike sought its aid in order to improve the quality of teaching. Programmed instruction ushered in the era of the industrialization of teaching and educational research.

With the advent of programmed instruction, books, machines and computers take their place alongside teachers at the conference table while teaching henceforth falls into the advertising domain and is bought and sold like any other product.

The healthy state of programmed instruction would seem to justify defining it in terms of an advertising slogan, and it is not hard to imagine a publicity campaign replacing the formal training of teachers.

The question: 'But what is this programmed instruction which you keep talking about?' would be answered by a poster or newspaper advertisement as follows: 'The modern solution to your teaching problems!' If a serious definition is required, we are as baffled as the philosopher who is asked to define philosophy. Like him we are tempted to reply: 'Come and take a look at what I do.' Such a reply may mean one of two things: either that programmed instruction is something practical and has to be experienced to be understood, or that it is merely whatever anyone wants to make of it. There is no shortage of definitions in the latter vein, from the broadest to the narrowest. For Professor Gagné, of Berkeley University, programmed instruction consists in making teaching models which take into account the initial and terminal response of the student, are graded in accordance with a detailed schedule and permit intermediate assessment of the strategies employed. This definition is somewhat lacking in clarity for a layman unless placed in its doctrinal context. The same observation could, of course, be made about other definitions. Hence, rather than supply some new definition which would satisfy nobody, we propose 'to take a look' and thereby give everyone the information he needs in order to construct for himself a satisfactory definition.

Skinner himself put forward his invention as a solution to the problems of the shortage of teachers and the increase in the number of students which were a source of concern to all countries. Although this hope has not been fulfilled, fifteen years later the rapid growth of programmed instruction and the general interest it has evoked are sufficient proof that it possesses merits other than those which make or mar a fashion. More will be said later about these qualities of programmed instruction which explain its ever-increasing success, qualities which Skinner regarded as of secondary importance or did not even suspect. In any event it is certain that the foci of interest have altered and diversified. However, the problems of teaching are still with us and as regards both quantity and quality are becoming ever more acute. It is of course teachers who feel these problems most acutely.

There are many who are over-enthusiastic about these techniques which promised an increase in efficiency. Others, on the contrary, have reacted warily, fearing the teacher would be supplanted by machines which would '*depersonalize*' education. In fact, 'it may realistically be supposed that the development and use of computerized data processing will be beneficial to teaching. There is a danger, however, of seeing the climate created by the use of computerized data processing and its extension, programmed instruction, invading and dominating education to such an extent that there might grow up, in addition to the desired adjustments and changes, a wholesale, uniform and to some extent unpredictable mentality—that of the mechanized approach.

'Perhaps the sway of reason itself can only be saved if we retain in teaching relationships a certain degree of irrationality, to match the rich variety of human personality' [1].[1]

There are yet others, whose ideas should not be underestimated, who in the name of what they call 'realism' have expressed considerable reservations: what means will be employed to train teachers in these techniques and to plan their large-scale use?

---

[1] There is a list of references at the end of each chapter; the number in brackets refers to the work quoted.

An exponent of programmed instruction almost invariably finds teachers giving vent to restrained or open scepticism, wholesale pessimism or unqualified enthusiasm. By dint of constant repetition these reactions eventually lose their impact and the exponent is often tempted to pass judgement on the ability of his audience to accept innovations. Reactions from all sides show significantly that the introduction of new methods implies a change in habits which goes against the grain of old and entrenched attitudes. There is an increasing desire to bring about these changes in attitudes. Programmed instruction also calls for such changes and if suitably presented can help to bring them about. The changes which it implies for teachers do not mean a radical break with the principles which guided them in the practice of their profession. On the contrary, it opens up new prospects, wider opportunities for putting those principles into effect.

The reality of programmed instruction is quite different from what is imagined and in no way justifies any of these extreme attitudes even though there may be grounds for legitimate fear or satisfaction, and even though many problems it claimed to solve are as yet unsolved. Somewhere between apologetics and indictment, and even though there is a good deal to be said on either side, there is room for more objective appreciation. But it should be emphasized that this objectivity is not readily acquired, nor is any easy way to it offered here. To arrive at it one must make a critical and informed analysis of the theories and techniques of programmed instruction, comparing them with other teaching techniques and with the general principles of teaching which centuries of experience have revealed.

This wealth of precautions and preliminaries may be found somewhat frightening. There is no cause for alarm. The practical side of programmed instruction can be mastered in less than a month. And a broad view of the theoretical references can be gained by reading through two or three books and a few journal articles. In other words, nothing in the training which programmed instruction requires resembles an initiation to the mysteries of some new rite. Neither in theory nor in practice is it the preserve of specialists. On the contrary, the teacher ought to be proficient in both, for he alone can put them to the test. Those who are at first impressed by the seeming complexity of programmed instruction are often deluded by the specialized language or jargon which cloaks the simplicity of its principles and ideas. It could all very well be included in the teacher-training course but this often seems a gamble, since the very title 'programmed instruction' is already somewhat off-putting. The second word is easily understood, but what, on the other hand, is hidden behind the first, redolent as it is of so much that is unfamiliar. It is important to avoid being impressed by the words; 'programmed' is merely a qualifying adjective and its significance lies in how it changes the nature of 'instruction'. These changes are real. If they are only on the theoretical level then they will be of little importance to teachers, who will not see their effect. If they are apparent in the class-room, then teachers and pupils will be the first to judge their impact, though they will have to use them properly. But before we can envisage this happy state of affairs, some general reactions which may prevent its ever occurring must be overcome.

THE USES OF TEACHING MACHINES

Teaching machines are credited with greater uses and capabilities than they really have. Both enthusiasts and critics are responsible for this. The former claim that they can teach, since what is taught can be analysed and therefore be disseminated by a machine. The latter assert that *how* something is taught is as important as *what* is taught and that automation is deadening. Who is right? No one is in a position to judge: it is impossible to analyse completely what is to be taught, and it is therefore difficult to find machines which can automate the transmission of what is to be taught; consequently, if there is no actual automation, there can be no deadening effect. There are, however, machines which can help us to confront the ever-increasing numbers of students. How can they be used to improve the quality of teaching also? We still do not know. But this does not mean we shall never know, nor that nothing can be done until we do. Numerous experiments have already been carried out, and even if we are still short of the goal in respect of both quantity and quality, at least the problems can be more clearly seen in all their complexity. In the search for realistic answers which satisfy both the demanding teacher and the national authorities, programmed instruction will make a significant contribution. The polemics of enthusiasts and detractors alike are thus pointless on the level on which they argue. They ought therefore to be invited to attend to the problems arising from the present experiments: they will discover fairly quickly that their opinions are not as far removed from each other as they thought. A look at the experiments which have been conducted will reveal that the subjects or concepts which can be analysed ('programmed') and taught by machines are not necessarily those originally imagined.

Similarly, when a particular subject is taught by a machine, it is found that the teacher, far from being excluded from the teaching process, becomes an even more vital part of it. There is as yet no evidence whatever to suggest that the conflicting claims of quantity and quality will pose a threat to the teacher or make him redundant. On the contrary. . . .

It is true that machines can take over certain tasks of the teacher such as the transmission of knowledge, the immediate correction of mistakes, drill, etc. But can it assume them all? This question raises in some minds another fear which is expressed more or less as follows: teaching machines—books, display devices or computers—ought to enable the child to learn on his own. The efficiency with which they do so will be in inverse proportion to the number of functions they assume. Thus they will only be able to reproduce a very diluted form of the teacher-pupil dialogue. The more unsophisticated the machine, the less it will be able to take the place of the teacher giving a lesson to his class.

A vital distinction must be made here. It is sheer common sense: the 'machine' is merely an 'aid' to the lesson. The pupil learns his lesson through use of the aid. The more complex the aid, the more complicated will be its use. For convenience sake we will therefore call the device in question an 'aid' and the lesson which it can present a 'programme'. This distinction reveals a characteristic of programmed instruction which could form part of its definition: it can be said to involve techniques which enable a 'programme' to be constructed and then entrusted to a certain kind of 'aid' which will fulfil the role of 'teaching machine'.

CONTENT OF THE PROGRAMME

The content of the programme and the way in which it is arranged may be affected by the nature of the device or aid. This consideration will assist us in examining more closely the objection already mentioned, which amounts to emphasizing that recourse to an aid, however elaborate it may be, impoverishes the teaching process by dissociating its elements and thus sacrificing its unity. It is true that there is dissociation of the different elements of teaching. However, to conclude that this dissociation results in impoverished teaching is to prejudge the way in which the aid and its programmes will be used. Why is this a hasty conclusion? Here again it is possible to give a direct and detailed answer but there is no guarantee that the information supplied by way of answer will be given the careful consideration required for reader acceptance. The teacher-educator will frequently note the constant preoccupation with preserving the advantages of teaching as a unity. This concern is not to be despised, but when it relies on arguments such as those above, it illustrates a form of unwillingness on the part of teachers to face up to the demands which the use of new techniques makes on them. Before the advent of the spinning-jenny, the weaver with his coiled thread produced cloth by a series of intricate movements which he performed very well. To increase production these movements had to be analysed and distinguished and in this way it was possible to allocate each of them to a different element of the machine. The breakdown of the movements and the separate elements of the machines brought about higher productivity. Why should the same not be true when there is a need for the 'mass production' of better-educated students? The spinning-jenny did not affect the quality of cloth but the quantity produced was enormously increased [2]. It is possible to imagine that the mechanization of teaching might produce similar results.

It is instructive for the teacher-educator to express the objections in these terms, because these questions raise others which are closer to those facing research workers today. It is easy to see how far weaving is removed from teaching. The components of cloth are well known and an observer can clearly distinguish the movements of the weaver. Are we, however, as familiar with the pupil as we are with the threads of a piece of cloth? Are we certain that in giving a lesson the teacher weaves one by one the individual threads of knowledge? These are the two goals programmed instruction has set itself in order to stand up to comparison with traditional methods. On the one hand it asserts that it is possible to define the potential of the student in relation to what he must learn. On the other, it claims to supply the methods and means of providing this tuition with a 'productivity' comparable to that obtained in industry. A metaphor will indicate how far short of these goals contemporary research still is: 'upstream', behind us as it were, programmed instruction undertakes to define a student's nature and potential in relation to what he must learn; 'downstream', still ahead of us, it indicates the actual tools to impart this knowledge. In between flows the river, representing the teacher at one with his pupils, his subject and himself! As we shall see, in its course it often meanders, not infrequently disappears altogether and when it re-emerges one is not always sure whether it is the same river or not.

Some will claim that we are taking excessive precautions to anticipate teachers' objections, but experience has confirmed that great weight must be attached to them. Many failures in programmed instruction derive from prejudices which have not been completely eradicated rather than from difficulties inherent in its techniques. Teacher-educators, school administrators and teachers must be aware of them since they must answer these objections and promote new attitudes both in teachers and in students. Indeed, one of the criticisms is the danger of setting teachers and school administrators at loggerheads.

Programmed instruction is merely one of a number of teaching aids, but its use will revolutionize school lessons since students will work by themselves at their own pace. Moreover, if there is to be a continual assessment of attainment and if progress from one class to another is based on these results, this will mean the end of the time-table which is carefully planned in the autumn and then followed to the end of the summer. All this is implied, as is shown by even the most elementary application of programmed instruction. There is no reason to suppose that this will result in complete chaos. On the contrary, it would appear that the more effort that is made to adapt to the individual student, the greater must be the diversification of methods and means; but it also seems necessary that teachers and administrators should plan the work in a more co-ordinated and structured fashion.

Teacher-educators cannot but endorse these objections. The teachers who voice them are anxious to know how to use programmed instruction and they easily foresee the difficulties they will have within the school or college in which they work. They are aware, and rightly so, that willingness, necessary as it is, is not everything. The problem which then arises is one of means, and this is even the very crux of the matter. Indeed, what benefit will teachers gain from a training which they will not have the opportunity to put into practice? This question can be answered in two parts: (a) we are convinced of the value of programmed instruction in teacher training, even if the teachers are not destined to use programmed lessons themselves; the costs, on this level, are low in relation to the benefits; (b) once one is dealing with actual use in schools, the objections do indeed assume their full weight. They will be considered again when we come to define the conditions under which programmed instruction can be used to give pupils the advantages (economy, efficiency, adaptability, etc.) it holds out.

We shall endeavour, on the basis of a concrete example [3], to define these conditions, bearing in mind that they must take into account local circumstances. It will, however, be for the local teacher-educators and administrators, once they have seen the different possibilities offered them by programmed instruction, to make a choice among them.

THE HISTORY OF PROGRAMMED INSTRUCTION

For the benefit of teacher-educators, frequent reference will be made to the objections, reservations or misunderstandings which they may expect to meet when themselves describing programmed instruction. One way to forestall these objections is to recall the historical background. Although this background may have very little to do with the theories and techniques of programmed instruction, it helps us to understand their development and their success. The present introduction will provide a broad outline; Chapter I will be devoted to the basic psychological principles which led to the invention of programmed instruction by Skinner; Chapter II indicates the lines along which these principles have developed into different types of programmed lessons; and Chapter III describes programming techniques and the part played by team work. Lastly, Chapter IV suggests certain guidelines for launching a programmed instruction project, pointing out some of the major problems which can be expected to arise.

First, some historical facts. Programmed instruction is too recent an invention to reveal anything more than wavering trends or tendencies in its evolution. Curiosity in regard to the theory and the resulting new terminology has frequently concealed the real reasons for its seemingly spectacular development. The general public regards it as a revolutionary gadget, but one which is still only on the drawing-board. The gadget in question is not totally new: it concerns teaching. The only problem is to know how far teaching is 'programmed'.

While some trace it back ultimately to Descartes, others to Galen or Socrates, programmed instruction is generally recognized as being the invention of the American psychologist, B. F. Skinner. The terms 'instruction', 'teaching' and 'education' have all been used, and there are nuances depending on which of the three it is desired to 'programme'. The reader will have to interpret the term according to his individual choice in the matter.

As for the old-established, everyday word 'programme', this has latterly taken on meanings which have made it both more specific and more popular. We are all familiar with the everyday usage, which relates to concerts, theatres, radio or television. The programme provides a descriptive notice of an event which is to take place. The significance is not the same for the organizer or the producer as it is for the viewer or the listener. In fact, for the organizer, a 'programme' specifies the detailed schedule of a number of co-ordinated actions and the allocation of roles and responsibilities with a particular end in view.

The word has gradually assumed another usage in the worlds of technology and industry. Thus we speak for example of production and sales programmes which are liable to alteration in the light of the results shown by periodic statistics. This alterability gives the notion of a 'programme' a new dimension: the plan for carrying out an activity in the light of preceding results [4].

A programme only takes on this dimension to the extent that it can be based on methods and instruments which can gauge the state of the medium in which it must be carried out and which it must alter.

In the field of information theory, 'A computer acts on a set of instructions which are collectively known as a computer programme. Each computer instruction is a minute step in the calculation and each computer programme a unique combination of many thousands of individual instructions which, in combination, cause the required calculation to be performed on the data. . . . Once established it is available for repeated use . . .' [5].

As far as the teacher-educator is concerned, he will have found in these definitions many elements which call to mind the one which teachers are up against every day. For the teacher, a 'programme' (or syllabus) is what he has to teach his students. In France, for example, the teacher learns precisely what he is to teach his students from the official *Programmes et Horaires* (syllabuses and time-tables) which determine the syllabus for the courses and the amount of time to be spent on each. In many cases he is also told the order which he must follow. The methods to be used are also suggested in the *Instructions Officielles.* The instructions and programmes thus provide him with a framework in which the operations are divided into sections (the sections of the 'programme') and the order in which they should be taken is indicated in the form of recommendations (the 'instructions'). This 'programme' which teachers are invited to follow, broken down into operations or sections, to be taken in a given order, apparently has all the characteristics of the other types of 'programme' mentioned earlier.

However, closer consideration will reveal appreciable differences between them.

An entertainer must fulfil expectations which he has raised or provoked, and the spectators are unaware of the measures which he has taken to do so. The student may be considered as being in the same position as the spectator. The information scientist organizes the tasks that the computer is going to carry out, taking into account at every stage those which have already been performed. The teacher is doing the same thing when he starts a lesson on the basis of the results of the preceding lessons. Thus the teacher's programme must satisfy two barely reconcilable requirements. First and foremost, the 'programme' compels him to follow the order of lessons without paying undue attention to his students' results (the 'programme' must be followed even if the students have not understood). The second requirement is that he should bear in mind effects which might lead to alteration of the order. Thus he has to steer a middle course between these two opposing requirements, bringing them into balance by his art.

The foregoing considerations bring to light a seminal concept which programmed instruction has been able to exploit. *Programmed instruction does not depend on the characteristics of a theatre 'programme' but on those of a 'programme' which operates an electronic machine.*

Etymologically, therefore, programmed instruction does not relate to the older meanings of the word 'programme', but to modern technological achievements. We may thus accept the following definition given by Caude and Moles: *Programme: a possible plan for co-ordinated action. Predetermined series of operations making up a process* [6].

If we have stressed the 'programmed' nature of this new method of teaching, this logically means that it is thought possible to anticipate accurately the development of operations which will lead a student to master what is to be taught. Predictions, schedules, checks and modifications in the light of results are at any rate words and phrases which teachers are beginning to use and appreciate. With programmed instruction they will have a means of using them with greater precision. They will no doubt be surprised to use a technical jargon which belongs also to the realm of the engineer, the psychologist, the technician or the planner. But the use of a common jargon is significant to the extent that it gives teachers access to groups which discuss the necessities of innovation in terms to which they are not accustomed. *Thus the shared understanding resulting from a common vocabulary goes beyond mere etymological definitions.* The interdependence which this favours and nurtures is instrumental in promoting a dialogue between teachers and others; in other words programming implies multidisciplinary team-work, because academics in different disciplines must take part in these discussions and must seek the collaboration of other specialists whose skills are felt to be necessary.

But there is no such thing as a programming technique which will in itself bring about the atmosphere conducive to interdisciplinary team-work. In no circumstances can programmed instruction be the means used to achieve this interdisciplinary approach of which we have been speaking. *However, the practical application of programming techniques, if given the proper slant, can show that it is no longer possible to tackle on one's own the problems to which they give rise.* Yet there are also signs of a trend to 'parochial programming'. Thus the tendency towards individual work may prevail, and the teacher may believe himself as polyvalent on the scientific plane as he has to be in the exercise of his professional duties. Fifteen years of programmed instruction are no guarantee that the trend has been reversed!

Again it might be imagined that the idea of efficiency would attract teachers to educational innovations. This is not the case. Perhaps it is necessary that others should define the implications of such an idea for it to be accepted. Or perhaps it is the pressure of needs that supplies the necessary incentive. This is seemingly borne out by the early history of programmed instruction, which developed against the background of research workers demonstrating the efficiency of new techniques but unable to gain recognition for them.

In the history of programmed instruction, 1926 and 1954 are the two key dates to be remembered.

In 1926 an American psychologist, S. L. Pressey described a small machine designed to give tests. He presented it as a 'simple apparatus which gives tests and scores—and teaches' [7]. This apparatus can set questions and suggest several answers from which the subject selects the one he considers correct by pressing a key. Intended as it was to simplify the testing of learning, Pressey conceived the idea that this system might be used for teaching. Despite the obvious interest of Pressey's plans for teachers and reformers, they were regarded with indifference for thirty years.

Pressey believed: '*These aids would probably do their particular work better (just as a calculating machine is more accurate than the old-time bank clerk). More important—they would leave the teacher more free for her most important work, for developing in her pupils fine enthusiasms, clear thinking and high ideals.*'

In 1954 Skinner also relied on psychological principles to recommend the use of 'teaching-machines'. Such a machine, he wrote, '*is a labour-saving device because it can bring one programmer into contact with an indefinite number of students. This may suggest mass production, but the effect upon each student is surprisingly like that of a private tutor. The comparison holds in several respects . . .*' [8].

The success of Skinner's schemes certainly stems from the discoveries he made and also from psychological or educational considerations. But other factors have come into play which are not directly linked to the teaching profession; they are characteristic of a general state of teaching, but also of what we might call the 'pressure of technology'.

THE NEED FOR EDUCATION

These needs have become alarming for two main reasons: the considerable growth in the demand for education in all countries, and particularly in developing countries; and the greater demand for further and more specialized training which is felt everywhere, but particularly in advanced countries.

Moreover, 'the need for education has grown faster than the increase in population. Undeniably there has been "an explosion in the schools",' [9] especially following the Second World War. But this 'explosion' is not an isolated fact. It is the consequence or cause of allied phenomena of rapid growth in economic, scientific, technical and other fields. Indeed, the rapid rates of growth noted in other fields represent additional 'needs for education'. These pressures have necessitated an urgent search for ways of meeting these enormous needs at a time when teachers are in short supply. New methods and techniques for a new situation had to be found—techniques capable of increasing the individual teacher's efficiency.

The shortage of teachers has other consequences which, however unimportant they may seem, are a very serious matter for the teacher. The increase in the quantity of education needed has not merely resulted in the research and development of mass media. It has also meant a demand for revised standards in the quality of education. A failure rate which was of less importance when only limited numbers were concerned becomes intolerable when the numbers assume massive proportions. On account of this, first methods are questioned, then content, and gradually the whole educational system is challenged. But it should not be thought that analysis of the causes merely leads to criticism relating to the quantity and the quality of education. The same factors which made this criticism necessary have also played a positive role and brought to the attention of educationists requirements which were previously overlooked. Hence terms such as efficiency, productivity or assessment of the educational process are used and reflect a new way of considering educational problems. In this sense educational thinking reflects both the renewal in technological thought and the contribution of the human sciences. This is particularly noticeable if the advances in cybernetics are considered.

It has for a long time been claimed that techniques which derive from cybernetics are very formal, by which is meant that

S.C.E.R.T., West Bengal
Date...25.2.82.
Acc. No. 2832

they are capable of being applied to any subject. This is true of the computer for example, which can help the sales girl, the documentalist, the translator, the research worker or the astronaut. But it is true only to the extent that the elements of the situations under consideration have been rigorously analysed. A computer only gives the expected answers if it is properly fed and correctly used. Thus a completely new spirit is required by this way of treating and imparting information. All the ellipses, the hidden meanings, the digressions accepted in ordinary communication have no place in the 'dialogue' with a machine. Thus we could say of the computer in our age what Mumford said of clocks in the Middle Ages [10]. To men who lived at the pace of nature and the seasons, clocks brought a new notion of time. In the same way computers give us a taste for accuracy by imposing it on us.

We are used to thinking that communication merely requires attention to be perfect, and this is particularly true of teachers. We now know that this is not so, and that we need the help of machines to make up for the deficiencies of our attention. Communication between machine and engineer takes place if the engineer can give the orders which must be carried out. These are the actions which make up the essential part of the programme: if carried out correctly they free one's attention for other matters.

If 'programmed' instruction is to bring into teacher-pupil communication absolute precision of this kind, then the planning of a lesson must take its inspiration from the model[1] used in these modern techniques. At first sight, it would appear sufficient to make a thorough analysis of everything involved in teaching activity in order to formulate the manner in which a machine could simulate this for pupils. The idea of such a machine coming to the rescue of the over-burdened teacher is as fascinating as it is striking. It has tempted more than one expert in programmed instruction, but it could be as illusory as it is attractive.

For the engineer who knows what the machine can do there are in fact no unexpected reactions. Where a student is concerned, the teacher is a long way from knowing how to elicit the desired reactions. For programming to be possible, a thorough knowledge of a student's behaviour in the course of learning a subject is vital. At first sight, psychology alone seemed able to provide this knowledge. It was therefore discoveries in this field which allowed machines to be used and introduced into the teaching world.

---

[1] Extract from lexical definition by R. Caude and A. Moles [6]. Model (mathematical usage): Abstract diagram to represent essential characteristics of structures of actual sets of objects. A simplified but schematic representation of a real phenomenon (Moles).

S.C.E.R.T., West Bengal
Library
371.3
UNE

25.2.82

What is particularly striking in this context is that the urgent need for solutions to the acute teacher shortage found immediate response in the pooled contributions of technology and psychology. The invention of programmed instruction at the very time when it was most needed might be thought providential, but any explanation in terms of providence risks concealing the influence of other factors which have acted less overtly, if not less effectively.

CONCLUSIONS

The educational system evolved in France at the end of the last century, for a long time produced the men whom society needed. As everyone recognizes, this system can no longer satisfy the needs of contemporary society. We speak of lifelong education, in-service training, and a continuous educational process. . . . Education must reach a public no longer composed of children and adolescents but of adults already employed in different sectors of the economy. The impulse these new requirements give to the renewal of educational concepts is very marked and it is not only the educational world which has felt its influence.

It has, in fact, been noticed that where learning is concerned, the actual aid or device is less important than what it provides: a machine which has no programmed lessons is as much use as a television set at times when there are no transmissions. A change has taken place, and its consequences are now being felt. In the business and industrial world, teams responsible for staff training are concerned not only with aids but also with 'programmes', in other words with teaching. At present in nearly all countries where programmed learning has become established, companies have been founded to produce 'tailor-made' training courses. To judge by their success and by the money invested in research into new aids, there can be no doubt that programmed instruction has opened up an interesting market.

Is this a consequence, a 'spin-off', of the interest in programmed instruction? On the contrary, it would appear to be one of the reasons for its success, even if courses and aids are no longer always sold under the name of programmed instruction. Indeed it would seem that this name is outmoded, and that programmed instruction is regarded as outdated because new teaching machines are being used. It remains to be seen if the use of new aids has really changed the contents and the methods of the teaching which they provide. What we have here is simply the effects of publicity. Changes in attitude are such that there is no longer any hesitation to speak of 'the teaching industry'. But the facts are clear: under the pressure of factors from outside the educational world, educational research has received a vigorous impetus, in relation both to its content and methods and to its technology and aims. Was programmed instruction carried along by the tide, or did it create and sustain it? No doubt both are true. Thus it has helped to direct teachers' attention to fields for which their training has not equipped them but in which their profession calls them to play a part.

Programmed instruction arouses much interest, passion and discussion. Its success may be explicable in terms of a convergence of factors which normally seem unrelated, but what is important is to note that these factors now have a role in education and must be accorded a place in the training of teachers. Thus it will be seen that programmed instruction cannot be presented as a technology which will change nothing in teaching practice. Moreover, if it is to result in the renewal of educational thinking, it is destined to come to the forefront of teacher training.

It has, in any event, achieved recognition. Neither teacher educators nor teachers can afford to disregard the technological and scientific contributions which it implies. In particular it has introduced the systematic use of experiments into teaching. It may therefore be hoped that it will prove an efficient tool for research work and thereby play an important part in attempts to renew teaching methods.

While it is true that programmed education has many advantages, its general use cannot be envisaged immediately. This is certainly not desirable so long as teachers have not been given the necessary training to familiarize them with educational technology and make them aware of the problems still raised by its inclusion in the educational system. These problems appear at the source, that is to say, in regard to the psychological principles with which Skinner endowed programmed instruction.

REFERENCES

1. GEMINARD, Lucien ('IGIP'). *Revue française de pédagogie* (Paris), April-June 1969.
2. FOLHEN, C.; BEDARIDA, F. *Histoire générale du travail*, vol. 3, p. 7-26. Paris, Édition Nouvelle Librairie de France, 1959.
3. UNESCO. *Rapport final, stage d'enseignement programmé ENSAC-Brazzaville*. Paris, Unesco, 1969. 74 p. (ED/WS/157.)
4. SAUVY, Alfred. De la théorie à la prévision par la méthode des modèles. *Revue d'économie politique* (Paris), no. 4, 1948, p. 488-512.

See also: GRANGER, Gilles. *Méthodologie économique*, p. 330-70. Paris, Presses Universitaires de France, 1955. 424 p.

5. WOODGATE, Henry S. *Planning by network—project planning and control using network techniques*, 1st ed., p. 362. London, Business Publications, 1967.
6. CAUDE, Roland; MOLES, Abraham A. *Méthodologie: vers une science de l'action*, p. 453. Paris, Gauthier-Villars, 1964. 456 p.
7. PRESSEY, S. L. A simple apparatus which gives tests and scores—and teaches. In: Arthur A. Lumsdaine and Robert Glaser (eds.), *Teaching machines and programmed learning*. Vol. I: *A source book*, p. 35-41. Washington, D.C., National Education Association of the United States, Department of Audio-visual Instruction, 1961-65. 2 vols. (First appeared in *School and society* (New York), vol. 23, no. 586, 20 March 1926.)
8. SKINNER, Burrhus F. Teaching machines. In: Lumsdaine and Glaser, op. cit., vol. I, p. 137-58.
9. CROS, Louis. *L'explosion scolaire*. Paris, Comité Universitaire d'Information Pédagogique (CUIP), 1961. 178 p.
10. MUMFORD, Lewis. *Technics and civilization*. Chapter 2. New York, Harcourt, Brace, 1934.

CHAPTER I

FROM PSYCHOLOGY TO PROGRAMMED INSTRUCTION

Many writers, particularly French writers, credit Descartes and the *Discourse on Method* with inspiring invention of programmed instruction. The idea is not entirely wrong, but it has given rise to false interpretations and unjustified comparisons. The theoretical foundations on which programmed instruction is based were provided by psychology, more specifically Skinner's psychology.

Programmed instruction, then, is not at the outset merely another teaching technique, but takes the form of the practical application of laws established in accordance with the rules of scientific method. It is therefore important to give teachers the basic knowledge which will enable them to judge whether the manner in which these laws are applied in teaching practice is warranted by the underlying psychological data. This will give them the information they need to understand the ways in which programmed instruction has developed since its beginnings.

In the specialist literature [1], Skinner is presented as the head of the 'behaviourist school'. As such he is both renewing and continuing a tradition. Programmed instruction would be incomprehensible if the changes which gave rise to it were not seen in the context of a current of thought. This tradition cuts across or runs parallel to other traditions originating in France, Germany and the U.S.S.R.

By using this theoretical material to induce teachers to view their teaching problems in a clearly defined doctrinal context, the teacher-educator can help them to employ programmed instruction and other similar techniques to advantage; this approach will also enable them to relate their experiments and innovations to the lines of current research.

FROM EXPERIMENTAL PSYCHOLOGY TO BEHAVIOURIST PSYCHOLOGY

All American psychology is stamped with an originality which P. Fraisse has described as follows:

While the subject matter, the body, of American psychology was inherited from the German experimentalists, its spirit came from Darwin [1].

America is a land of immigrants. The welcome it has extended to all has not prevented it from moulding its own tradition and becoming in its turn a fount of inspiration and a guiding light. . . .

The growth of experimental psychology in America follows the pattern of her towns and industries. . . . No sooner had psychology arrived on her shores than she set about refashioning it, giving it in the process a clearer awareness of its own problems [2].

According to the first quotation above, the starting point of American psychology was the research work of the German psychologists who in the latter part of the nineteenth century endeavoured to give psychology scientific aims and a scientific method. This brought to a close the age of introspection or 'rationalist' psychology with its reliance on the individual consciousness to conduct the investigation into its own nature and the accompanying phenomena.

Around 1872-75 William James put into practice his 'principles of psychology'; this is the title of his book which was published in 1890 [3]. For him the psychologist should no longer be concerned with what happens *in* the consciousness, but should study the phenomena *of* consciousness, i.e. the physical phenomena manifest in the environment, and other relevant phenomena. These the psychologist endeavours to grasp and explain through the *function* they fulfil.

According to James, *consciousness, like the other functions, in all probability evolved because it is useful* [3]. The definition of consciousness as a function, then, refers to the idea of its 'utility'. In the Darwinian tradition invoked above, the successful performance of an act is the principle which determines conservation of the function and thereby of the individual. This theme, to the elaboration of James's 'pragmatist' philosophy, imbued the thinking of his successors, whether they were directly inspired by him or not. All subsequent writers were to seek to describe consciousness as a factor in the adjustment of the individual to the environment in which he is evolving.

Dewey, following upon James, formulated a more systematic theory of 'functionalism'. The main lines, as summarized by Fraisse in the above-mentioned book, are as follows:

The first important contribution by this 'functionalist' school is Dewey's article 'The Reflex Arc Concept in Psychology' (1896). His aim is a critique of atomism, which with him refers not to the components of consciousness, but to the reflex arc. What counts for him is not the individual components of reactions, nor the sum total of such components, but the co-ordination between them. Even a simple reflex is in itself a co-ordination: for there is no stimulus and *response, a stimulus is a stimulus only when it calls forth a response, and a response is a response only because there has been a stimulus. The reflex, according to Dewey, is a means of establishing a useful co-ordination* [4].

Thus his critique of atomism in psychology involves refining the concept of utility and applying it with greater precision. Breaking down an act into its external components (stimuli) and internal components (reactions) raises inextricable theoretical problems if one wishes to explain their conjunction. The simplest or most 'elementary' act—the reflex—in fact appears as something homogeneous, which only interpretation breaks down into isolated components. The act itself consists entirely in the *co-ordination* of the stimulus and the response: *It is the act of a living being which is making an adjustment to its environment* [4].

Despite his contribution to psychology, Dewey became best known for his theories in education, which he presented as an application of his research work. This is worth stressing. For after Dewey psychology almost invariably leads to some educational application. The connexion seems obvious since the psychologist, when studying behaviour, discovers constants which are also laws of learning and which he then need only apply.

Stanley Hall and his school followed next. The organizers of experimental psychology, they defined and extended its scope as well as popularizing the main ideas we have already outlined. The writings of J. McKenn, Cattell and Thorndike, in particular, constitute a source book for the founders of programmed instruction. Of these Cattell is known as the 'inventor' of mental tests. While we need hardly elaborate on the success such tests have enjoyed well outside the bounds of psychology, it is worth mentioning that they very soon came to be used as a means of testing behaviour in the learning process. And as we shall see below, programmed instruction continually relies on mental tests, either to check the effectiveness of learning or to facilitate it.

Thorndike is known for his research on animal intelligence. This was the subject of his doctoral thesis, presented in 1898. His experiments were guided by the concepts of 'reflex' and 'conditioning'.

In order to follow the contributions made by this tradition down to Skinner, the originator of programmed instruction, we must refer to the work of Pavlov. Diagram 1 shows the general line of development which we are summarizing here.

PAVLOV AND THE CONDITIONED REFLEX

Everyone knows about Pavlov's experiments on dogs, and how they were made to salivate and secrete gastric juices simply by the ringing of a bell. But what concerns us here is the *method*, i.e. the way in which the experiments were conducted and the *hypotheses* on which they were based. Skinner was eventually to challenge these in a novel series of experiments, and for this reason it is worth tracing the chain of reasoning—guided by experiments—which led to the evolution of programmed instruction.

We have no intention here of writing the history of psychology, but only of using psychological data as a means to demonstrating that this science underlies programmed instruction and is, therefore, of capital interest to students training to be teachers. Our intention, in other words, is to give a short summary of the subject, with more particular emphasis on certain aspects.

Conditioned reflex

A few words to remind readers of what this term implies.

An 'experimental' dog is hungry. He is given a meat ball. It is observed that, when this happens, he secretes gastric juice in a flask directly connected up with his stomach; also that he produces saliva.

We conclude from this that the mere sight of the food suffices to set in motion the mechanisms which accompany the satisfaction of this need.

Readers will remember the rest of the experiment, now become famous. At the second stage, the presentation of food is associated with the ringing of a bell, and the appropriate secretions are produced. Subsequently, the bell is rung, but without producing food, and the secretions continue to be produced. A 'conditioned reflex' has been set up, as illustrated by Figures 1, 2 and 3 below.

But despite the simplicity of the experiment, and the fact that far more complex reflexes can be 'set up', it is important to note that both the methods used and the results obtained refer to a particular interpretation.

As regards methods Pavlov, as we know, invented the 'tower of silence'. In the end, it was enough for the experimenter to turn the door handle or for the dogs to recognize him by his smell

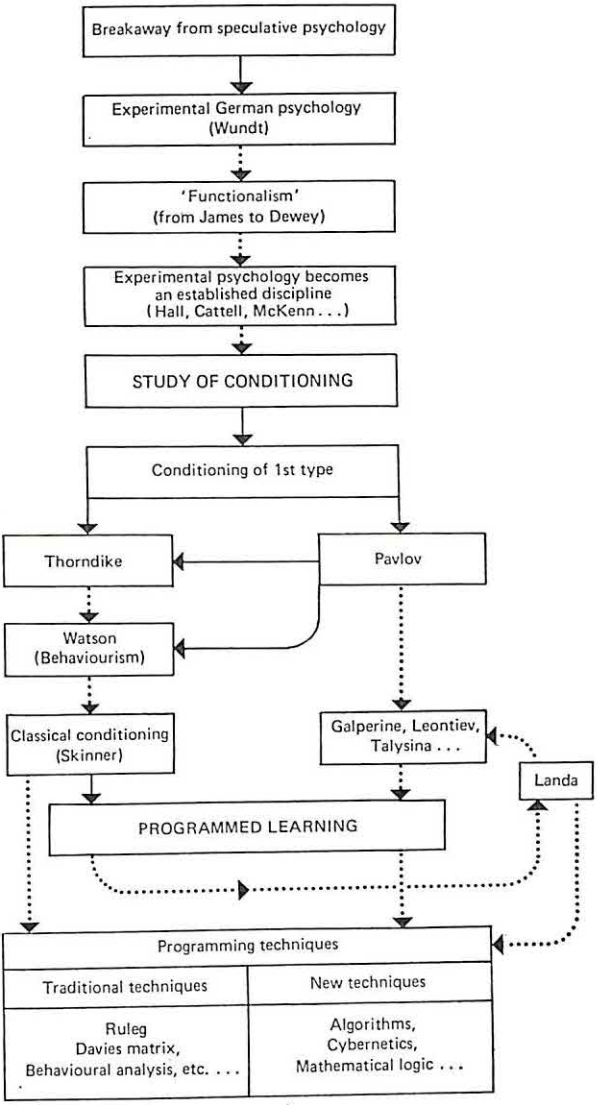

Breakaway from speculative psychology
Experimental German psychology (Wundt)
'Functionalism' (from James to Dewey)
Experimental psychology becomes an established discipline (Hall, Cattell, McKenn . . .)
STUDY OF CONDITIONING
Conditioning of 1st type
Thorndike
Pavlov
Watson (Behaviourism)
Classical conditioning (Skinner)
Galperine, Leontiev, Talysina . . .
Landa
PROGRAMMED LEARNING
Programming techniques
Traditional techniques
New techniques
Ruleg
Davies matrix,
Behavioural analysis, etc. . . .
Algorithms,
Cybernetics,
Mathematical logic . . .

DIAGRAM I.

in order to make them secrete gastric juices. In an effort to cut out the intervention of such random factors and retain only those between which he wished to establish a relationship, Pavlov evolved this idea of a 'tower of silence', a term used to designate

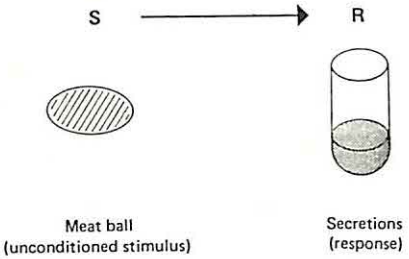


FIG. 1. Unconditioned reflex.

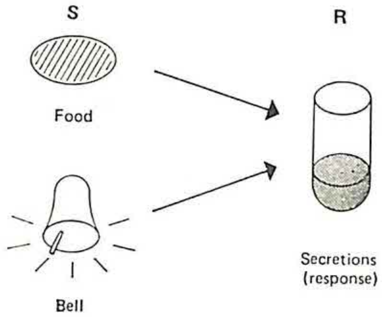


FIG. 2. Associated stimuli.

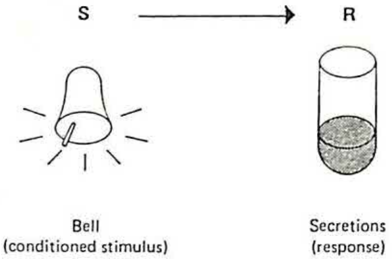


FIG. 3. Conditioned reflex.

an experimental environment so designed as to exclude all but the factors to be studied. As we shall see, Skinner, in one sense, adopted a completely different procedure.

As to the principles, Pavlov always interpreted his results with reference to neurological mechanisms. It is for this reason that his conception is described as 'realist' in so far as it explains acts of conduct (responses) in terms of the functioning and structures of the nervous system.

On the basis of these methods and principles, Pavlov built up a whole theory of the system of reflexes, from the simplest, which he demonstrated in laboratory experiments, to the most complex—such as that of language—for which he thought he had found an explanation.

This led to other consequences having a direct bearing on teaching. On the basis of the study of reflexes, he established rules and described a training system which was subsequently to be called 'conditioning'. Thus, Pavlov's study of behaviour was followed naturally by the application of his discoveries. Also we see that animal experiments led quite naturally to experiments with human subjects, the same scientific method being used in either case.

We shall make the same observation, subsequently, with regard to other schools of psychology: the aims pursued and the methods used lead to the discovery of laws of learning; and these laws, once discovered, come to constitute the rules on which scientific learning is conducted. Moreover, since such discovery can be applied forthwith, there is no time-lag between discovery and application.

This observation relates to the 'history of ideas' on which teachers should reflect. It also indicates the increasingly important part played by psychology in teaching. But it is no longer a question—as it used frequently to be—of knowing a little psychology; what is needed is to know enough psychology to be able to consider ways of making use of it in the class-room.

FROM THORNDIKE TO WATSON: THE ARRIVAL OF THE 'BLACK BOX'

Thorndike appears to be very close to Pavlov's ideas, except that he refuses to explain psychological facts in terms of physiology alone. Significantly the subject of his doctoral thesis (1898) was 'Animal intelligence', and his ideas made him the pioneer of animal psychology. Thorndike, when watching animals learning, observed two facts: the first was that the best way to fix responses is by connecting them with the satisfaction of a need—the 'law of effect'; the second, that animals proceed by 'trial and error'.

Watson, a pupil of Thorndike, attached the utmost importance to conditioned reflexes from the very early stages of his work on animal psychology. Though he followed Pavlov's work very closely, he remained unconvinced by both Pavlov's results and his conclusions. He took the view that Pavlov's experiments on elementary reflexes were valid and even brilliant, but that his interpretations lay outside the experimental domain, being either exaggerated or impossible to verify. There is no means of knowing precisely either how a stimulus is received or how the response occurs. Two things only are certain: the stimulus and the response. These are elements which can be analysed, observed and measured; but the links between the two escape observation, so that nothing at all is known about them. We have no right, since this cannot be observed scientifically, to interpret the relation between the stimulus and the response in terms of the nerve centres and neurological mechanisms.

Thus Watson, though not condemning Pavlov's experimental methods, refutes the bases and principles of his explanation and he does so in the name of the very criteria inherent in these methods. Any attempt to deduce more than these methods themselves supply is suspect, and belongs to the realm of fantasy or unchecked hypothesis. The gist of his criticism is that references to consciousness or to the physiology of the nervous system yield nothing verifiable in the study of individual behaviour.

But if one is to adopt this standpoint and take exception to the principles applied for the study of certain phenomena, one must, to be logical, put forward other principles which can, at the very least, be applied to the phenomena in question.

Watson proposed that we should confine ourselves to what can be *observed* and *controlled*, i.e. precisely to the stimulus and the response. About what happens or what exists between the two we know nothing. This means, in principle, that it should be disregarded: between the stimulus and the response lies the 'black box', wherein nothing can be observed (Fig. 4).

Watson did not say that nothing goes on inside the 'black box'. He simply emphasized that any statement made on this subject, since it could not be based on observation, was merely a hypothesis which could not be scientifically verified or checked. The 'black box' is thus presented as a *working hypothesis*, which both simplifies the psychologist's task, by making it unnecessary for him to resort to unwarranted interpretations, and offers him exciting prospects

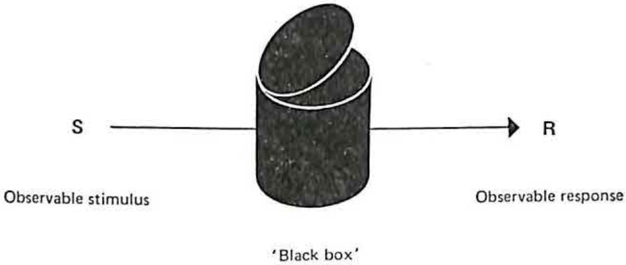


FIG. 4.

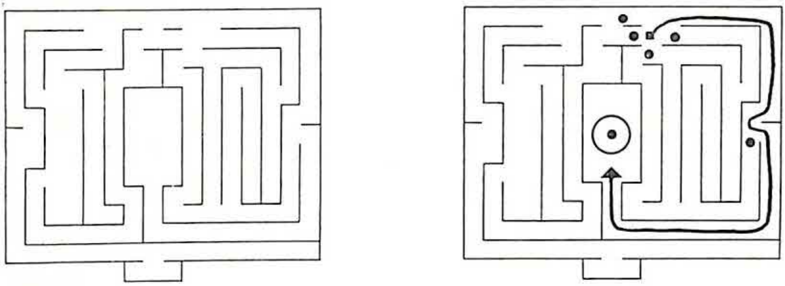


FIG. 5. Diagram of the Hampton Court maze.

■ Departure point

● Electric shocks

⊙ Arrival = reward

in that it makes possible the study of behaviour in relatively simple experimental conditions [5].[1]

Watson applied this hypothesis in several astounding experiments involving the use of rats and mazes (Fig. 5).

The experimenter arranges a maze through which the rat has to pass from the point of entry to the point of exit. The maze has no roof so that the behaviour of the rodent can be observed, in order to see how it proceeds from entry to exit. At various points in the maze there are several possible routes the rat can take; if he goes wrong, he receives a slight electric shock to dissuade him from following that particular path.

What observations are made, and what conclusions can be drawn from this experiment? Watson notes that the rat 'tries out' the various possible paths open to him. When he makes a mistake, the electric shock makes him try another route. And this continues until he reaches the exit, where he receives a reward (he is either given food or allowed to run free). Two other points are also noted: when he makes a mistake, and incurs a penalty as a result, he takes 'avoiding action'; and success is achieved gradually, but more and more quickly, through trial and error.

From this are deduced 'laws of learning'. The first law, a general one, emphasizes that behaviour is characterized by 'trial and error'. Further, it is observed that the 'law of effect' applies in so far as failure leads to action to avoid failure in future, while success fixes behaviour that will result in further success, the alternation of the two accelerating the process of learning, i.e. discovering the 'right behaviour' which will lead without error to the exit. In this way we arrive at a constant relationship, or laws, governing stimuli and responses without reference to what happens in between.

---

[1] Herein lies the principal theoretical justification of 'behaviourism', which consists in the study of behaviour by methods based on the hypothesis of the 'black box'.

No effort is made to study how the nerve centres of the rats are constituted in order to ascertain the laws for controlling their behaviour. What is done is to observe the effects regularly produced by failure or success, a combination of the two gradually fixing the required pattern of behaviour. It is interesting to note the part played by error in the 'law of effect' thus demonstrated. It is doubtful whether error plays any real part in the teaching of behaviour, but the importance attributed to it may be due to the method used for the experiment (the administration of penalties in the form of electric shocks). In other words, it is possible that the law deduced from this experiment reflects the conditions of the experiment no less than the actual modes of behaviour of the animal.

On the basis of his experiments Watson was able to set out 'laws of behaviour', of which the three main ones are those of proximity or recency, practice or exercise, and effect. Proximity: the tendency to repeat the last response made simply because it is the closest. Practice: the fact that a response is more firmly fixed the more often it is repeated. Effect: the fact that 'correct' responses are more readily repeated, which accentuates the effects of the proceeding laws.

From his laboratory experiments Watson boldy deduces a theory of learning and teaching. Thus he states:

Give me a dozen healthy infants well-formed, and my own specific world to bring them up in, and I will guarantee to take any one at random and train him to become any type of specialist I might select—doctor, lawyer, artist, merchant-chief and, yes, even beggar-man and thief, regardless of his talents, penchants, tendencies, abilities, vocations, and race of his ancestors [6].

The idea that assimilation capacity has nothing to do with 'aptitudes' or 'talents' is based largely on these analyses.

But these statements still had to be proved. It had to be shown *in practice* that the 'laws of behaviour' could be used as a guide to planned learning. According to the theory, the transition to practical application was *natural*, i.e. offered no contradictions in the experimental framework in which it was presented. The transition had to be made, however, and the credit for doing this belongs to Pressey.

PRESSEY'S CONTRIBUTION

Though modest on the psychological and experimental plane, Pressey's contribution is important on account of the future prospects he opened up.

He constructed a small apparatus [7], designed to make it easier to test students' assimilation of knowledge. According to him, the mechanical design of this device was such as to make it possible to do this on the basis of the 'laws of behaviour'. In practice, its functions were far wider.

The device presents a list of questions, to be replied to by selecting one of several possible answers. The student cannot go on to the next question until he has found the correct answer to the first one (either first time off, or after several tries). The machine is also able to tot up the errors.

The results obtained were very curious. Quite unexpectedly, testing resulted in the elimination of errors. The apparatus designed to *test* turned out also to be capable of *teaching*!

Pressey made an attempt to explain this on the basis of the psychological data of this time; he refers to the laws of behaviour:

The 'law of recency' operates to establish the correct answer in the mind of the learner, since always the last answer chosen . . . is the right answer. The correct response must almost inevitably be the most frequent, since the correct response is the only response by which the learner can go on to the next question; and since whenever a wrong response is made it must be compensated for by further correct reaction [8].

In cases where it is put to use for teaching, as Pressey wished it to be, it is essential to stress the significance of this law. The whole apparatus of teaching appears to minimize the part it plays; or at any rate fails to give it a constructive part to play in facilitating, influencing or guiding the process of learning.

The 'law of exercise' is thus automatically made to function to establish the right response. Since the learner can progress only by making the right reaction, he is penalized every time he makes a wrong answer by being required to answer the question one more time, and is rewarded for two consecutive right responses by the elimination of that question, the 'law of effect' is constantly operating to further the learning [8].

The 'law of exercise': the right response must be repeated. The 'law of effect': repetition of the right response accelerates the process of learning. Thus these three laws were put into practice by Pressey's little apparatus. The machine designed for testing what children had learned could be used as a teaching machine. Why were they never used for this purpose? Skinner replies as follows: *Pressey's machines succumbed in part to cultural inertia; the world of education was not ready for them* [9].

But he adds: . . . *they also had limitations which probably contributed to their failure* [9]. Skinner holds that these limitations stem from the theoretical bases on which Pressey worked. There are also, no doubt, other limitations, as we noted in the previous chapter, and as E. Dale also affirms [10].

But whatever the 'limitations', theoretical or otherwise, Pressey must be given the credit for one thing: he foresaw the coming of a teaching system inspired by the findings of psychology and benefiting from the contribution of technology. In thus putting forward the idea of combining technology and psychology, he may be said to have been the initiator of educational technology before audio-visual media or programmed instruction were ever heard of. When all is said and done, it was through the 'back door' of psychology that programmed instruction was introduced. However, Pressey's approach still attached too much importance to error.

About 1938, Miller and Konorsky drew attention to certain specific phenomena in the conditioning process. They noted, when making a study of reflexes, that an animal, on receiving a reward for some spontaneous action, will be eager to repeat it. Though the original action was not provoked by a stimulus, it does constitute a response which can be fixed.

Moreover, what fixes an action is not a stimulus, but the reward given subsequently. It is as though the stimulus came *after* the response. Was Pavlov's or Watson's diagram still valid? Should we write:

$$S \longrightarrow R$$

or, on the contrary $R \longrightarrow S$?

All Skinner's work is in the nature of a reply to this question . . . and shows that it is wrongly stated.

SKINNER

Skinner belongs to the purest behaviourist tradition. His strictures directed against the 'inner man' are reminiscent of Watson's violent diatribes against the murky 'black box' of consciousness! He endorses the criticism of inner causes, at the same time making it more general:

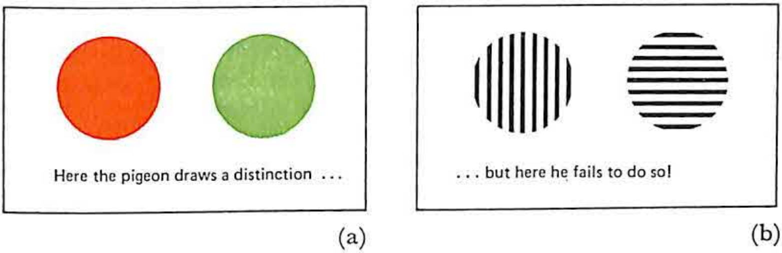

Here the pigeon draws a distinction ...
... but here he fails to do so!
(a)
(b)

FIG. 6.

The objection to inner states is not that they do not exist, but that they are not relevant to a functional analysis [11]. *We must confine ourselves to observable events* [12].

Whatever the criticisms levelled against behaviourism, programmed instruction stems from this concept and that of Pressey.

By a few remarkable experiments Skinner effected the transition from the laboratory to the class-room.

Skinner's pigeon experiments

1. Let us observe one of Skinner's pigeons in its experimental cage. But first a preliminary word about it.

After several experiments of the Pavlov type, the pigeon proves capable of distinguishing between colours; it can easily be trained to distinguish between red and green (Fig. 6 (a)). On the other hand, when an attempt is made in the *same experimental conditions*, to teach it to distinguish between (i.e. to recognize) vertical and horizontal stripes, it fails (Fig. 6 (b)).

This double experiment, carried out in the conditions recommended by Pavlov, is important on account of the deductions made from it. It may, in fact, be concluded that the pigeon possesses the neurological and physiological capacities necessary for distinguishing colours, but does not possess the same capacity for distinguishing two types of stripes.

It is important to stress these preliminary conclusions, since they are the first stage in a process of reasoning which draws on scientific experience and may perhaps go beyond.

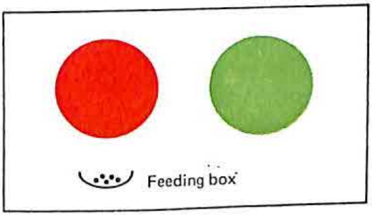


FIG. 7.

2. Skinner then takes one of these pigeons which are apparently incapable of distinguishing stripes, and places him in an illuminated cage on one of the walls of which there are two circles (Fig. 7) of the same size. One is red, the other green.

The first step is to teach this new pigeon to distinguish between red and green.

He is allowed to do as he likes, for as long as he likes. But when he pecks the red circle, he will receive bird seeds in his feeding box fixed just below the red circle. We shall therefore wait until he does so. When he is hungry, he gets excited and will eventually peck at the red circle *without being incited to*.

He does so, and receives the seeds. He is kept under observation. He flies round pecking, and comes back again to peck at the red circle. Whereupon he receives more seeds. It is observed that he goes on pecking more and more frequently at the red circle. After a certain time has elapsed, even though the seeds may be replaced by a certain sound, he will continue to go on pecking as regularly as before.

In the end, both the seeds and the sounds can be dispensed with: the pigeon will peck at the red circle directly the circles appear.

Conclusions of this second stage of the experiment. We manage to 'condition' the pigeon to make the same responses as with Pavlov's methods, but by the use of completely different methods.

Instead of isolating the factor which is to serve as the stimulus, we *allowed the situation to develop*. It was not until the expected reaction was obtained that the bird was rewarded. The reward thereupon served as a stimulus, leading to the repetition of the reaction at shorter and shorter intervals. As we see, the experimental situation here is radically different from that proposed by Pavlov.

Pavlov selected the factors to be studied by eliminating all the rest, thus constructing the 'tower of silence'. Skinner, for his part, appears to make no attempt to produce a situation by process of elimination. On the contrary, things are so arranged as to lead the animal *itself*, by his actions, to select from amongst numerous stimuli, those factors which it is desired to retain. Thus the selection of these factors is operated by the animal *during* the experiment and not by the experimenter *before* the experiment.

This is a fact of considerable importance. It makes it possible to imagine that for a given subject involved in any complex situation, the whole process of learning will consist in gradually inducing him, by the use of appropriate means to select from the experimental situation, and subsequently devote his active attention to those elements it is desired to fix.

The importance of this idea warrants asking teachers to give it serious consideration: the difference in the prospects opened up by this method, as compared with that of Pavlov, would constitute a useful subject for reflection and discussion.

Another point to note is that the desired results can only be obtained on condition that the *subject* plays an active part in the process: it is, in fact, he *who dictates or controls the pace of the learning process*. This is also an important point to retain for discussion.

3. The experiment goes much further than these points. The question now is, whether or not pigeons can be taught to distinguish between two types of stripes, horizontal and vertical. Immediately after the first phase described above, the pigeon is allowed to continue pecking at the red circle. Little by little, vertical stripes are made to appear on this circle while, at the same time, horizontal stripes are shown on the green one (Fig. 8). The pigeon still gets seeds whenever he pecks at the red circle, the seeds gradually being replaced by something else (the ringing of a bell, for instance); this too is eventually eliminated.

In the last phase of the experiment the pigeon is faced by nothing but stripes, the colours having been eliminated. The intervals between the rewards or whatever replaced them have gradually been lengthened until, eventually, a correct reaction produces nothing at all. It is then observed that the pigeon distinguishes infallibly between the vertical and the horizontal stripes, even when other factors in the experiment are changed.

The most striking point about this experiment is that Skinner makes pigeons do things that Pavlov believed to be impossible. However, we must not allow ourselves to be dazzled by the picturesque aspect of the experiment. Skinner carried out many other experiments which, though much more fascinating, were no more important as regards the information supplied to amateurs of animal lore; he also carried out others, less spectacular, but of greater scientific interest. Let us therefore confine ourselves to the experiment described above, and consider what contribution it makes to the study of the differences between Pavlov's results and Skinner's.

Skinner, by his results, proved a number of things. The first, which is of considerable practical importance, is that behaviour can be understood without reference to the nervous system or to introspection. Better still, he proved, on the basis of experiment alone, that Pavlov was wrong in believing that pigeons (for

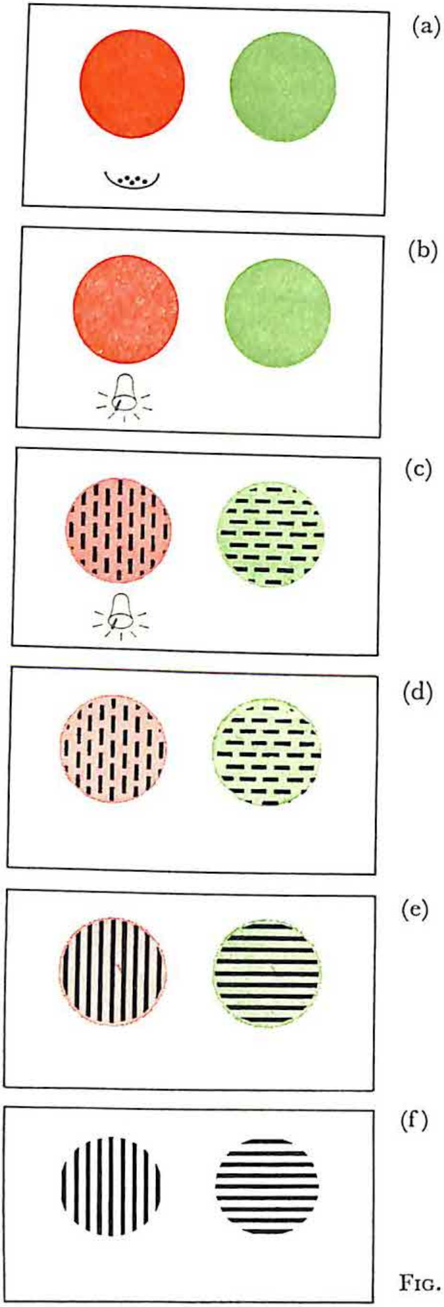


FIG. 8.

example) are incapable of certain forms of behaviour because their nervous system is insufficiently developed.

Why does Skinner's pigeon learn better than Pavlov's dog?

This question deserves very special attention, for it is on the basis of his reply that Skinner was to evolve all the main principles of programmed instruction. According to Skinner, the answer to this question is suggested by the form of the experiment, and the manner in which it was carried out. Let us therefore take another look at this experiment and ascertain its specific features.

The difference between the experimental device used by Skinner and those used by his predecessors is evident. The pigeon's cage makes no provision for penalties: no electric shocks such as rats experience when running a maze, no prior starving, no means for compelling the attention by eliminating everything the animal is not intended to learn. As Skinner himself points out this is an experiment without violence, without punishment and without any 'negative stimulus' [9, p. 76]. But it is not out of kindness to the animals that they are treated so well; attractive though this explanation may be, the real reasons lie elsewhere.

Another point observed is that, at the beginning, the animal is left free to act as it likes and make what movements it chooses, without the slightest let or hinderance. In other words, the animal is placed in a milieu such that it is free to respond to stimuli of all kinds. This is a situation totally different from that of Pavlov's dog in his 'tower of silence'.

It is not a matter of the experimenter creating an artificial situation in order to select those factors which he wishes to study. On the contrary, the selection of these factors is left to the animal itself, this activity indeed constituting the learning process. It is true, of course, that the learning process is controlled, in so far as the purpose is to induce the animal to adopt a certain mode of behaviour (aim of the learning process). But it is nevertheless the animal itself which, *through its activities*, builds up the process.

The experimenter confines himself to rewarding those actions which further the aim pursued, but without restricting the animal in any way, even as to time. The experimenter may be said to have prepared a programme of work for a pigeon which is blissfully unaware of his intentions and is merely going about its own occupations. He leaves the pigeon free to do as it likes, and all he does is to reward the bird when it performs the operation scheduled in its programme.

The programme in the experiment described just now was to teach the pigeon to distinguish between two sets of stripes. By the end of the experiment, the pigeon had carried out its programme without being subjected to pressure of any kind.

Initially, the pigeon does as it likes; but its actions are gradually influenced by the rewards given. It is seen to speed up its repetition of the actions expected of it, to seek to ascertain which actions will produce a reward. Thus the bird progresses *at its own pace* which, it is noted, becomes progressively faster.

Another point emerges from the foregoing: that no notice is ever taken of any errors, wrong actions or hesitations. The experimenter never intervenes—to give seeds or make a sound—except when the desired action is made. *No notice is ever taken of failure, only of success*, which the entire effort is devoted to reproducing or repeating.

Thus the pigeon proceeds freely, at its own pace, advancing step by step without ever being penalized for its errors. All these reasons show *why* the experiment is spectacular; but they do nothing to explain *why* it succeeds. And this explanation, following the experiment, refers us back to the theory, in order to find out *why* the qualities or characteristics demonstrated were encountered.

The answer to this question resides in what Skinner calls the theory of 'reinforcement' or 'operant conditioning'.

'Reinforcement' and 'operant conditioning'

Miller and Konorsky had already remarked that it was possible for 'conditioning' to be achieved in conditions other than those defined by Pavlov or Watson. It is this type of conditioning that Skinner highlights; it was given the name 'passive conditioning' or 'conditioning of the first type' as opposed to the type of conditioning studied by Skinner's predecessors.

As Skinner shows, operant conditioning[1] brings into play, *in combined form*, the three laws formulated by Pressey [7, p. 49] 'in combined form' in so far as the three interact exponentially.

These three laws must therefore, Skinner affirms, be restated in an entirely new form, on the basis of the new starting point constituted by the experiment on our pigeon.

The experiment showed that any given subject—the pigeon's (or human) brain being deliberately left out of account—acted *effectively* if certain precautions were taken. The acts expected of the animal are rewarded, whereupon it tends to repeat them. Rewards *reinforce* the expected actions.

---

[1] The operant is defined by the property upon which reinforcement is contingent: the height to which the [pigeon's] head must be raised [13].

We are not here causing an action to be repeated several times in order to fix it, but fixing it by means of repeated rewards when it is performed.

This leads to a new law incorporating the three others: a correct response (in this case, to a question not posed), when followed by a reward, will be repeated. The response (reaction) is established by the recompense (stimulus) given; the laws of recency, effect and practice should therefore be reinterpreted on this basis.

Thus the stimulus comes *after* the action, so that it cannot possibly provoke the action. It operates *retrospectively*, *reinforcing* an action already performed. In this way reinforcement is said to have a feedback effect on the response.

This is Skinner's great discovery—that reinforcement must be used in order to shape behaviour effectively. 'The change in the frequency with which the pigeon raises its head constitutes a process of operant conditioning' [13]. This has been borne out, verified and further demonstrated in other experiments. Skinner concludes that it is essential to apply as many reinforcements as possible. For the experimenter who wishes to make a given animal capable of a certain type of behaviour, 'the learning programme will consist of applying reinforcing contingencies', arranging as many opportunities as possible for satisfaction. Comparative studies show that a great deal of time is gained thereby and that the subject advances much farther and is capable of far more than could be foreseen.

Thus it is in the theory of reinforcement that the 'law of effect' assumes its full significance. Certain aspects of it had of course been dimly perceived before, but, by and large, the most negative ones. What now come to light are its positive features. According to Skinner this is what was lacking with his predecessors and this explains why they found it difficult to apply the laws of psychology to teaching practice.

Now that the meaning of these laws has been broadened, we are at last in possession of the theoretical bases necessary to proceed to the application stage. [9, 10]

THE APPLICATION OF SKINNER'S PSYCHOLOGICAL THEORIES TO TEACHING

There is one objection which teachers constantly make when told about these experiments: that it is not legitimate to apply to human beings laws of behaviour established for the animal kingdom. How, they say, can observations valid for animal behaviour also apply to human learning?

Replies to this question. These objections are not valid if we remember the basic hypothesis on which these experiments were carried out.

Let us think for a moment of the 'black box', which rules out any explanations referring to 'thoughts', 'neural paths', etc. . . . i.e. anything about which it is impossible to state *how* they affect behaviour. And it is precisely because of the refusal to take account of such factors that it was possible to get the pigeon to perform actions of which it was said to be incapable.

Yet people will insist that there is a fundamental difference on the experimental plane between men and animals. It was the limited nature of this very argument that the experiments demonstrated.

The use of this material often meets with the objection that there is an essential gap between man and other animals, and that the results of one cannot be extrapolated to the other. To insist on this discontinuity at the beginning of a scientific investigation is to beg the question. Human behaviour is distinguished by its complexity, its variety, and its greater accomplishments, but the basic processes are not therefore basically different. Science advances from the simple to the complex; it is constantly concerned with whether the processes and laws discovered at one stage are adequate for the next. It would be rash to assert at this point that there is no essential difference between human behaviour and the behaviour of lower species; but until an attempt has been made to deal with both in the same terms, it would be equally rash to assert that there is. A discussion of human embryology makes considerable use of research on the embryos of chicks, pigs and other animals. Treatises on digestion, respiration, circulation, endocrine secretion and other physiological processes deal with rats, hamsters, rabbits and so on even though the interest is primarily in human beings. The study of behaviour has much to gain from the same practice [14].

But Skinner also gives another reply to this objection. Animals learn by being active, and their activity goes towards shaping their behaviour. Certainly, the same is true of men. There was a time when we thought children's minds had to be filled up by making them memorize a whole string of facts. But nowadays, everyone agrees that people only learn through activity, through constructing something themselves.

Those who assert that there is a fundamental difference between animals and people find it hard to explain why. The real reasons for holding this view frequently stem from the attitudes denounced earlier (cf. Introduction), or at any rate this is one of the occasions on which such attitudes come out most strongly. It is advisable, when presenting Skinner's views, to seize the opportunity for joint consideration of his method and its implications or get the class to apply them to specific problems dealt with in the literature [10-14].

There is a second objection which is sometimes made, though seldom in so many words. Since it is a very serious one, it should perhaps, if not made spontaneously, be deliberately provoked. It is this: that what differentiates men from animals is language, the capacity to express their experiences and feelings. This animals are not capable of doing.

Skinner has devoted a whole book, entitled *Verbal Behaviour* [15], to this subject. In this, Skinner recognizes that verbal expression consists of specific variables of differing degrees of complexity; but these variables can, in all cases, be submitted to the control of determined stimuli, which are, it is true, of an essentially verbal character. The use of words and the handling of language have thus all the characteristic forms of behaviour such as are habitually subjected to the process of operant conditioning in the course of experiments. It is for this reason that Skinner has no hesitation in declaring that verbal expression is a form of behaviour like any other (apart from a few specific characteristics).

Skinner refutes all the reasons which might be adduced to prove that language is the distinctive characteristic of man or rather he uses them for the purpose of showing that the use of *language is a form of behaviour* like any other. As we shall see, this is one of the points round which the most heated arguments both for and against Skinner centre.

Be this as it may, Skinner remains quite adamant in his conviction that the transition from theory to its application in education is justified. On what grounds does he defend himself?

For teachers the question will be posed in these terms: *on the basis of what principles can the laws of learning be applied to the teaching of humans* in such a way as to make this teaching *effective, rigorous, controlled* and *adapted to its purpose?* The principles and their significance are as follows.

The step by step principle

Effectiveness depends on frequency of reinforcement. When teaching a specific discipline, this means that measures must be taken to provide as many opportunities as possible for practice, i.e. for reward or reinforcement. This involves dividing up the information to be communicated into small units or doses, each requiring activity sanctioned by reinforcers. Thus for instance Skinner declares that for the teaching of arithmetic several thousand reinforcers should be distributed, instead of several hundred as at present [16]. The idea of dividing the material to be taught into mini-slices is inspired not, as is sometimes averred, by the requirements of cybernetics, but by the need to ensure maximum effectiveness by increasing the number of reinforcers.

This results in increasing the number of stages in the learning process, each of which constitutes a 'step'. It is important to stress this idea, which is central to programmed instruction: progress is made step by step, and the more steps there are, the greater the number of reinforcers, i.e. of stimuli to learning.

This bring us to the first principle to be applied in programmed instruction: that the *subject* must be divided into *units* of information, in order that progress may be made by small steps, and the largest possible number of reinforcers supplied.

In teaching devices, the reinforcement is a direct consequence of the student's behaviour, usually in the form of confirmation of the correct answer [17].

Activity

The second principle is that pupils must act on each 'unit of information' by means of exercises provided to assimilate it.

Success

Children will learn as quickly as pigeons do if they are given the possibility of succeeding as often as possible. The activity required for the assimilation of knowledge must lead to success. The implications of this third principle are very important: error and failure must be avoided at all costs because they are obstacles to learning.

Immediate verification

For there to be satisfaction and success, the pupil must know that his action is correct. Hence he must be able to compare his reply with the correct answer before passing on to the next step: there must be immediate verification.

Learning progresses logically

In the process of learning, activity should centre increasingly on what is to be taught. In the case of the pigeon, success was the means whereby to fix its attention on certain modes of behaviour which it was desired to have repeated. This should also apply to humans. Thus an attempt will be made to avoid all superfluous elements likely to distract the pupil's attention. Learning progresses logically. In this way it will be possible to speed up the process, i.e. to provoke increasingly complex modes of behaviour, gradually increasing in difficulty. Progress is graded.

The principle of individual pace

Lastly, as in the case of the pigeon, no attempt is made to force the pace or set time-limits. Indeed, it is for this very reason that the process of learning is accelerated with this method. Pupils are left to proceed at their own pace: this is the principle of 'individual pace', thanks to which it will be possible to individualize instruction.

Summary: step by step; active participation; success, reinforcement; immediate verification; logical, graded progress; individual pace.

Here then are the main principles on which programmed instruction is based. As we see, each of these principles is based on the laws of behaviour discovered by Skinner in his laboratory experiments. A teaching system based on these principles and laws should therefore be *effective* and genuinely scientific, in comparison with the traditional empirical approach. Skinner presents programmed instruction as a new and scientific teaching method. By 'teaching method' we denote all the various ways and means by which, in order to teach given material, we take account of all known factors involved in learning the material (psychological, socio-cultural, etc.) and employ various techniques, aids, words or verbal images, devices, etc., conducive to its transmission and assimilation by the pupils.

Thus, as regards method, programmed instruction is designed to produce two revolutionary changes: first, to individualize teaching, at the very moment when mass education has to be envisaged; and secondly to disregard error, and this at a time when academic failure is becoming an acute problem. The first of these changes is easily comprehensible; the second will probably be less so, and it will be necessary to return to it as occasion arises.

Skinner and the place of error in teaching

Skinner's experiments convinced him of the primordial importance of satisfaction in the process of learning. We have followed his observations and interpretations relating to his experiments on pigeons. On the basis of these experiments Skinner thinks there is sufficient ground for stating that error is bad because it is associated with lack of satisfaction. Hence the position he attributes it in ordinary pedagogical methods.

CONCLUSIONS

The principles governing application of laboratory data to teaching practice do not follow directly from the data themselves. Skinner was right in pointing to the consistency of the theoretical premises from which programmed instruction derives. However, it is not fair to say that he founded his teaching system wholly on the results of psychological research, thus turning teaching into a branch of applied psychology. Whilst stoutly maintaining his conviction that the maximum use must be made of the laws of behaviour, whose validity has been demonstrated by experiment, he also admits that their practical application involves so many variable factors that it is scarcely possible to proceed in the same way as in a laboratory. Nevertheless, he insists that teachers could learn much from experimental methods and 'models'. While it is not possible to attain the same degree or rigour as in science, such procedures and techniques can be subjected to scientific requirements and a scientific attitude, which is essential to all scientific activity.

By offering individual teaching adapted to the particular capacities of the individual pupil, programmed instruction will gradually affect the entire organization—the very conception—of school life. Teachers with classes of ten, thirty or fifty pupils cannot effect this transformation unaided. But precisely because scientific rigour is not possible without clearly spelling out the operations to be performed, the execution of these operations can be entrusted to machines. The fact that technology—in the strict sense of the term—intervenes at this point does not mean it encroaches on the role of the teacher, whose job it is to work out the 'programmes' and make sure of their adaptability.

One last remark. The above discussion of the theoretical bases of programmed instruction may appear to some readers to be an incursion, albeit necessarily a brief one, into a sphere far removed from the day-to-day work of teaching. This is only partly true; we know that everyone is fully aware of the need for changing the methods and content of teaching, but we know too that merely to ponder on experience is not sufficient. It is clear that if we are ever to go beyond the stage of general criticisms and the resulting general recommendations, we must investigate other spheres, related domains, which may sometimes provide more specific ideas. It is for this reason that we think it useful to dwell on certain theoretical aspects, even if their practical applications are not immediately perceptible.

REFERENCES

1. FRAISSE, Paul. *Traité de psychologie expérimentale*. Vol. 1: *Histoire et méthode*. Chapter 1, p. 506. Paris, Presses Universitaires de France, 1963.
2. ibid., chapter 1, p. 135.
3. JAMES, William. *Principles of psychology*. New York, H. Holt, 1890. 2 vols.
4. FRAISSE, Paul. op. cit., chapter 1, p. 137.
5. NAVILLE, Pierre. *La psychologie du comportement*. Paris, Gallimard, 1963. 379 p.
6. FRAISSE, Paul. op. cit., p. 50. (Actual reference is: WATSON. *Behaviorism*, p. 82. New York, 1924-25.)
7. PRESSEY, S. L. A simple apparatus which gives tests and scores—and teaches. In: Arthur A. Lumsdaine and Robert Glaser (eds.), *Teaching machines and programmed learning*. Vol. I: *A source book*, p. 35-41. Washington, D.C., National Education Association of the United States, Department of Audio-visual Instruction, 1961-65. 2 vols. (First appeared in *School and society* (New York), vol. 23, no. 586, 20 March 1926.)
8. ——. A machine for automatic testing of drill material. In: Lumsdaine and Glaser, op. cit., vol. 1, p. 42-6. (First appeared in *School and society* (New York), vol. 25, no. 645, 7 May 1927.)
9. SKINNER, Burrhus, F. *The technology of teaching*, p. 32. New York, Appleton-Century-Crofts, 1968. See also: Teaching machines. In: Lumsdaine and Glaser, op. cit., vol. 1, p. 139 *et seq.*
10. DALE, Edgar. *Historial setting of programmed instruction*. In: *Sixty-sixth yearbook of the National Society for the Study of Education*, Part II, Section I, Chapter II, p. 28-54, Chicago, Ill., University of Chicago Press, 1967. (This article discusses the military interest in research on educational psychology, the analysis of industrial tasks and its application to teaching. However, the author points out that, 'Characters in 1945 expressed disappointment over the fact that so many educators with ideas were not interested in the materialization of ideas' (op. cit., p. 44).)
11. SKINNER, Burrhus, F. *Science and human behavior*. Chapter III, p. 35. New York, Appleton-Century-Crofts, 1963.
12. ibid., chapter III, p. 36.
13. ibid., chapter III, p. 66-7.

14. ibid., Chapter III, p. 38.
15. ——. *Verbal behavior*. Chapter 4, p. 80 *et seq*., chapter 8, p. 203 *et seq*., chapters 12-18. New York, Appleton-Century-Crofts, 1957.
16. TALYSINA. Theoretical principles of programmed learning. Course of lectures given at Moscow Polytechnic Museum. Moscow, 1968. (French translation in preparation.)
17. PORTER, Douglas. A critical review of the literature on teaching devices. *Harvard educational review*, vol. 27, no. 2, 1957.

CHAPTER II

TYPES OR MODELS OF PROGRAMMED COURSES

It is not intended to include here information commonly found in popular works on this subject. When such data are used or referred to, it will be for the purpose of drawing the attention of teacher-educators to points which frequently cause teachers difficulty, and giving them hints on different ways of presenting the types or models of programmed courses. We shall also give, in passing, definitions of the main specialized terms used in programmes.

To set out the various types or models of programmes would appear, at first glance, to be a simple matter; one has only to count the large number of articles on the subject published in specialized journals. But mere description of them is not enough to enable teachers to grasp the differences or the analogies between these different models.

It will, therefore, not be out of place to dwell at some length on this point, in order to show teachers how it is that Skinner's psychology can produce more than one method of presentation and that it can be applied in several different ways.

In an endeavour to reply to these questions, we shall refer to the arguments which have raged round programmed instruction since the outset and we shall try to discern the main grounds for dissent. Thus this chapter, designed to be of a descriptive nature, will in fact complement the chapter on history and psychology. The contents of the other chapters will be similarly flexible, which is to some extent inevitable owing to the fact that we tend, whenever concentrating on one particular aspect of the subject (psychological, historical, pedagogical), to change or refine our views on other aspects.

We shall begin with the type of programmed lesson conceived by Skinner himself, representing the most orthodox adaptation of the principles and ideas presented in the preceding chapters. There also exist other types, which we shall present subsequently, explaining the differences between them and Skinner's model.

THE SKINNER PROGRAMME

Before embarking on any description, we shall provide teachers with a practical example, and give them an opportunity to study a lesson in the same way as their pupils would. It is preferable, for reasons which will become clear later, to give them a 'programmed course' designed for the pupils of the class they themselves will be teaching. This is chiefly because the aim should be to present teachers with a teaching situation similar to that they have experienced, so that they may be able both to understand and to criticize it.

We give below two examples.

EXAMPLE ONE [1]

A set of frames designed to teach a third- or fourth-grade pupil to spell the word 'manufacture'.

1 MANUFACTURE means to make or build. Chair factories manufacture chairs. Copy the word here:

. . . .

2 Part of the word is like part of the word FACTORY. Both parts come from an old word meaning MAKE or BUILD.

MANU . . . . URE

3 Part of the word is like part of the word MANUAL. Both parts come from an old word for HAND. Many things used to be made by hand.

. . . . FACTURE

4 The same letter goes in both spaces:

M . NUF . CTURE

5 The same letter goes in both spaces:

MAN . FACT . RE

6 Chair factories . . . . chairs.

EXAMPLE TWO

Page 1

No. 1 *Idea of sets*
In mathematics, SET is the word applied to something very specific. We are now going to learn what this word indicates by taking simple examples.

The following words denote things with which we are familiar:—group—team—tribe—family association—troop—crowd—swarm.

A crowd, for example, is a 'collection' of individuals.

Similarly each of the other words listed above denotes a . . . . of things

Complete by writing one letter in place of each of the above dots. The response is given on page 2, top left-hand corner.

Page 2

Answer
No. 1
Collection

No. 2 *Idea of sets*
The tribe, the family, the swarm, the crowd are collections. Each of these collections comprises *several* objects.

But we do not always know exactly what these collections are composed of.

Can a group be composed of pupils, of soldiers or of houses?

YES NO

Underline your response then check it on page 3, top left.

Page 3

Answer
No. 2
Yes

No. 2 A group may consist of pupils, of houses, of soldiers, etc.

We do not know *precisely of what* it is composed.

Someone may tell you: 'There was a large crowd in the square last evening'.

A crowd is a 'collection', like a group.

But do we know precisely what the collection forming this crowd is composed of?

Reply here, 'yes' or 'no': . . . . .

Page 4

Answer
No. 3
No

No. 4 We know neither who the individuals forming the crowd are, nor how many there are.

Take care to remember this: when it is not known precisely what a collection is composed of, it does not convey to us the notion of a set.

Is it known exactly what the French football team that played on 10 May 1965 was composed of?

Reply here: . . . .

Page 5

Answer
No. 4
Yes

No. 5 Of course it is: It is possible to find out exactly what 'the French football team that played on 10 May 1965' was composed of. You yourself don't know exactly, but you could find out by reading the newspapers which described the team that day.

This example gives the idea of a SET, since it is known precisely what this collection is composed of.

Not all collections convey the idea of a . . .

Complete the above, inserting one letter in place of each dot.

Page 6

Answer
No. 5
Set

No. 6 We can find many examples of collections where we know precisely what they are composed of. It is only these collections which convey the idea of specific sets.

Examples:

'the set of tables in our refectory';
'the set of table legs in our refectory';
'set of figures (from 0 to 9)';
'the set of my marks for last month'.

In all these examples, the idea of a . . . is specific because we know precisely . . . . each set is composed.

Complete the above by replacing the dots by letters.

Description and terminology

The above examples are extracts from programmed lessons. The term 'sequence' is often used to denote an entire programmed lesson, and the term 'programmed course' to denote a set of sequences relating to the same subject.

A sequence, as shown by these examples, is composed of several parts (see Fig. 9 (a) below). Each part is clearly separated from the others, and a graphic representation of the layout is a means of indicating this more clearly. In this case, for example, the whole is enclosed in a large rectangle; this is one of the reasons for the use of the word 'frame' to designate a part of a sequence. The contents of a frame are called an 'item' but, since the layout varies considerably, there is a tendency to drop the distinction between frame and item, and to use the word item for both. Strictly speaking, then, a sequence is composed of a certain number of items, which are usually numbered and studied in numerical order. In this case it is item No. 3 which is being studied.

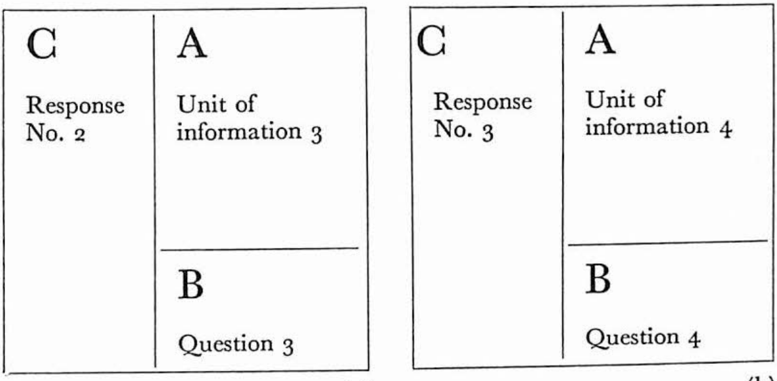


FIG. 9. (a) (b)

The item itself consists of several parts, which are in some cases separated. The above diagram shows one way in which it may be separated, but there are also other ways. One part gives a piece of information (part A) which is limited, i.e. elementary, and quantitatively as small as possible.

The presentation of this information is followed by a question or an exercise on it (part B), to which the pupil must reply before he can continue to the next item, for instance No. 4. (Fig. 9 (b)). In part C, he will find the correct response to the question he has just been asked. He may thus compare it with the response he has just given and check whether his response is correct or not. This done he can pass to the following piece of information (A) in item No. 4 and reply to the question following it. He will then check his response in part C of the following item, continuing in this way until the end of the sequence. As we see, a printed sequence is very easy to handle with a few simple instructions and a few examples.[1]

Each sequence is, as a rule, rounded off by tests or questionnaires. The purpose of these is to enable the teacher to check progress. One such test, the so-called initial or pre-test, is presented to the pupils before the sequence, in order to make sure that they possess the requisite knowledge or have reached the requisite standard to embark on that particular sequence; the second, the final or post-test, is presented after the sequence, to make sure that its contents have been properly assimilated.

This composition is characteristic of the Skinner-type programme. Our description of it is based on sequences presented on paper, i.e. where the aid takes the form of a book or exercise book, this being the most common form. Other types of aid such as machines can also be used. Although in the case of a machine the layout is different, the composition of the sequence remains essentially the same, with pupils following the same type of process, made up of unit of information, question, response, correct response and so on.

We may find this type of very rigid organization surprising and wonder how it incorporates the principles of sound learning as defined by Skinner.

Why are Skinner's sequences composed in this way?

In other words, we should like to know if this presentation, using various aids, makes it possible to adhere faithfully to the principles listed under 'Summary' at the end of the preceding chapter, which are based on the application to teaching of the laws of behaviour.

As early as 1954 Skinner gave a clear answer to this question. In 1969, we find him emphasizing again that the avoidance of error at all costs is essential for learning in the best conditions. As applied to teaching, to learning by human beings, the main concern is the avoidance of error, and to this end, it is essential to eliminate all digressions liable to distract pupils' attention, all obscurities and difficulties that pupils would be unable to overcome. Why? Because error stops and discourages the pupil, and the repetition of error is tiring and an obstacle to learning. Failure is harmful, success beneficial, as proved by the experiments carried out in the laboratory. It is essential, therefore, to exploit the fact that success leads to success, progress to further progress. Each sequence must be composed, down to the minutest details, in accordance with this rule.

---

[1] Many people are understandably afraid that pupils may find it difficult to handle either a programmed course or a teaching machine. The results of observations made on this subject are reassuring, as illustrated by the experiment described below.

Young children learnt to handle the most highly developed machines and succeeded in communicating by means of typewriters. By the end of a few sessions, which were filmed without their being aware of it, it was noted that many of them had become so familiar with the whole of the apparatus that they were trying to type out their answers with their toes!

In order to increase the success rate and hence also the amount of satisfaction received, we shall simplify the information pupils are required to assimilate. Thus each item, or each of these 'small steps' will be reduced to a minimum. In order to make each step as small as possible, information will have to be cut up into the largest possible number of units. As we shall see in the next chapter, composing units of information is not always easy; but it is via these units or steps that the pupil gradually progresses. Some conscientious experimenters have even calculated that an item should average about thirty words! We endeavour, generally speaking, to ensure that each unit or item presents a certain minimum amount—a quantum—of difficulty to the pupil, to whom it must be given stripped of any verbal or other obscurities. Thus the expression or presentation of the information contained in each item must conform to certain rules, which are not always easy to respect. If the programming techniques are satisfactory in this respect, we may be said to have obeyed the first principle of Skinner's teaching system, that of the step-by-step approach.

Every unit of information constitutes a stage of progress. It is accompanied by an exercise, a question, but this is entirely separate from the problem the pupil is asked to solve after the lesson. The question refers to the actual unit of information conveyed by the item, and is thus strictly limited. But there is more to it than this: it is not a question *about* a piece of information supplied, designed to check the assimilation of that information. On the contrary, it represents the *means* whereby the pupil, by replying, is able to assimilate the information; in other words, it incites the pupil to perform an operation, i.e. to do that which makes learning possible. Skinner strongly emphasized this idea: that people only 'learn' operations by performing them, and only 'grasp' them by carrying them out in situations necessitating them.

The question terminating an item is not merely a secondary element designed, for instance, to make sure that the pupil is following or keeping up, it is rather an integral part of the learning process. And, important though it is to ensure the 'purity' of the learning process and the information provided, it is even more important to take care as to what is asked and how it is worded. If programming techniques are fool-proof in this respect, we shall then be in a position to obey the second principle of Skinner's teaching methods—that of active participation. The term 'constructed response' is also used in this connexion.

Observation. At this point, the following objection is frequently made: learning is effective if it provides many opportunities for success; but it is not an authentic process unless the pupil takes an active part in it, unless he has to face problem-situations. The activity principle and the principle of success appear to be incompatible. There might be a tendency, in fact, to confront the pupil with problems which he will always be able to solve. But is a problem to which he is sure of finding the answer a real problem?

Teachers often ask this question. And many of those who are won over to programmed instruction tend to set real problems or real questions, i.e. to place pupils in situations such that they are liable to make mistakes. Whatever their underlying motives, this attitude indicates a fundamental lack of understanding of programmed instruction; and we must not hesitate to point out and condemn it every time we meet it.

The point is that Skinner's views on the question and the related activity are completely at variance with traditional views. His aim is not to propose an exercise on the basis of which to *classify* or rank pupils in accordance with their ability to overcome difficulties. All ideas of classifying pupils are scrapped: they must all succeed in everything. And this is only possible by giving them prospective satisfaction. That the difficulty of the problem is graded to the level of the student does not mean that there is difficulty: on the contrary, Skinner declares that this method enables students to overcome obstacles gradually increasing in difficulty.

After the pupil has worked out his response, he is shown the correct one with which to compare it and check whether he is right. Skinner even gives figures for the rate of success: 95 per cent of pupils, he says, should give the correct response to 95 per cent of the questions. The remaining 5 per cent are attributed to errors of no importance (slips of various kinds). The pupil must succeed, and everything will be done to ensure that he does. But this does not mean setting him exercises which he already knows how to do or which he is already able to do—on the contrary, the aim is to teach him how to do them. Giving the means of learning *successfully* does not mean to say that success is sought for its own sake and at all costs. The essential thing is, still, to teach something. When we succeed in doing so, the principle of *success* is respected.

The pupil is able to check immediately that his response is correct; and this provides the motivation for him to pursue and redouble his efforts in the study of the subject. *Immediate confirmation* provides the essential reinforcement, the means of sanctioning and enhancing the effects of success. It has a retroactive (or feedback) effect on the action immediately preceding it, fixing it more effectively than failure, which discourages the learner because the reason for it is not understood.

It is already clear that it should be possible with programming techniques to prepare questions which relate to the information given, correspond to the pupil's level and call for clear responses which can be verified by the pupil and so act as reinforcers. But this, as we may imagine, is no easy matter. We shall deal with it in the next chapter.

Progress will be logical and graded from one item of the sequence to the next. Graded because, clearly, the complexity of the operations the pupil is required to perform will gradually increase. Hence we shall talk about the gradual transition from simple to complex operations.

But why logical? It is easy to imagine how embarrassed a teacher of geography or mathematics would be if the psychologist-programmer began to talk about the logical basis which his course should respect.

The teacher will most certainly ask what is meant by the logic of a subject that is to be taught. The subject, of course, comprises various concepts, linked by relations which can be manipulated in accordance with certain rules within a set of reasonings, some of which will be considered right, others wrong, according to whether they fit in with the rules or not. But it should be asked whether these concepts, relations or reasonings can be mastered in any other way except by putting them into practice. They possess then no other logic (or, to use technical language, internal structure) save that by which they are learned.

But the best way of learning them is, surely, by adhering as closely as possible to the laws of learning. Thus the *logic* of a concept or a subject is the logic which is adopted for teaching it to others, following the laws of Skinner's psychology.

Many people will think it going too far to use the experiments of behaviourist psychology as ground for telling specialists how the subjects they are teaching are organized. This is equivalent to stating, for example, that mathematical concepts are to be defined and interrelated according to the manner in which they are taught. Concepts, relations and modes of reasoning, according to this view, are subservient to learning. To state this in even more controversial terms: the material to be taught has no inherent mode of organization of its own, only that conferred on it in the processing of learning it. According to Skinnerian behaviourist theory, this is perfectly legitimate; at all events, no experimental means of proving the opposite hypothesis exists, whereas this hypothesis has proved its efficacy in action.

The conclusion to be drawn from this is self-evident: the correct organization of the material—what we shall call its logic—is that which makes it possible to construct a coherent learning system, one which obeys the laws of behaviour. To put it more bluntly, it may be said that a good learning system is that which makes it possible to construct and thus discover the internal logic, structure or arrangement of the material to be taught.

This statement may appear, at first glance, to have no bearing on reality, and even to be incorrect. A teacher who studies the subject he is teaching observes that it is constructed in a certain way and possesses a structure or an organization of its own, independently of him; and all his experience as a student appears to confirm this view.

The teacher-educator for whom we are writing may doubt that this is, in fact, the case. If he asks teachers to prepare small programmed courses (sequences) during practical work sessions, he will notice that the teams involved are up against a difficulty from the very beginning: they find it hard to speak of the organization of a given part or section of their subject, and keep on referring to the way in which they teach it in a specified class. They perceive the structure and organization of their subject through the means they use for teaching it. And this approach is so fixed in their minds that they may find it difficult to imagine other methods or other ways of communicating their knowledge. But this is in itself a clear illustration of the Skinner theory which they find so shocking. It might, for this reason, be wiser, once the problem has been stated, to take no further action until practical exercises have given everyone an opportunity to pause and reflect on how he sets about preparing his sequence.

Observation. The reason why we have paid so much attention to an objection which is frequently raised against programmed instruction is that it can be used as an example in the discussions which will inevitably follow presentation of this subject. Simply to provide a group of teachers with information, however well it is done, affords no guarantee that they will assimilate it. To limit oneself to that is to incur the bitter disappointment of seeing them devise sequences much worse than their ordinary lessons, though they themselves might think them far more satisfactory. It is proposed here that, during the first stage, every idea inspired by new theories—Skinner's or others—should form the subject of a separate discussion. At the second stage, the practical work stage, such ideas will be taken up again: the objections raised to them will be recapitulated and students invited to give further thought to them in the light of the difficulties which have actually arisen in practice. In this way the initiation to programmed instruction can contribute to teacher training by encouraging a critical attitude directed towards real problems.

To return now to our fifth principle: that progress must be logical and graded. Logical because it conforms to the laws of behaviour; graded because by spacing out the obstacles and employing reinforcement it will be possible to accelerate learning and ensure the grasp of increasingly difficult material.

Lastly, pupils can take their own time. This eliminates one of the main drawbacks of the present method, the other two being the danger of failure and the classification system. Skinner adduces several arguments in favour of this principle, which is designed to eliminate the sense of guilt produced by failure or inability to keep pace. And indeed, there is little reason why a child of 6 or a student of 16 should be bound by the strait-jacket of the one-hour lesson. Those who can get through in less time are bored, those who need longer are discouraged and out of their depth. At this point, teachers are bound to put common-sense questions, such as what the quick learners are to do while their slower classmates are still at work, and what will be done with the very slow ones who have still not finished when the time comes to begin the next lesson with the whole class.

These objections are extremely serious ones. Impressive though the principles of programmed instruction may be, they will be of small benefit if they cannot be applied. To attempt to dodge the issue is futile: it involves scrapping the whole notion of the one-hour lesson and of a class assembled for such a lesson. The question of what is to be put in its place—in a school or college organized on the basis of a convenient time-table laying down the hours of classes, lessons and teachers once and for all at the beginning of every year—remains unanswered, or rather, there is no cut-and-dried, universal solution to the problem. But we should always remember that the question nevertheless remains on the file, alongside all the arguments put forward by psychologists such as Skinner. Before considering what is to be said on either side, it would be wise to await the conclusions drawn by teachers from their own experience. It seems preferable to wait, for the simple reason that the very general criticism to which such questions give rise results in solutions, being offered in no less general terms. Discussions started at this level, and with no more precise data, frequently tail off into generalities which merely cause irritation and discourage a serious, well-informed approach to the subject.

Conclusions

We discussed, in the previous chapter, how and on what principles psychological data could be applied in teaching; and we have just seen how, both in its form and in its use, the programmed sequence exemplified the pedagogical principles deriving from these data. Though the transition from theory to practice would appear to be a natural one, we have surmised that it may not be altogether smooth. The system may perhaps have flaws, the nature of which we have suggested in the course of discussing some of the commoner objections to it.

Skinner's theories do not represent the whole of programmed instruction. Other theories, which, unlike his, do not involve the introduction of a whole scientific apparatus, have also been put into practice. The fact that Skinner's theory does not stand alone makes programmed instruction a city rather than a single edifice. And one of the first buildings we shall notice in that city is that of Crowder.

THE TYPE OF PROGRAMME DEVISED BY CROWDER [2]

Origins

Crowder is not a trained, professional psychologist. As a technician, he had occasion to deal with vocational training, which brought him face to face with problems of efficiency, of improving and accelerating learning without increasing the percentage of dropouts and failures. His job, at one time, was to train technicians in the repair of aircraft engines.

Crowder observed that the situation of a student technician faced with an engine which had broken down is entirely different from that of a student setting out to study mathematics: the latter is completely ignorant of the subject he is required to study and then to apply, whilst the former is familiar with aircraft engines.

The problem for the technician is how to find the cause of an engine breakdown as soon as possible without first dismantling the whole engine to put it right. The cause is unknown, and the mechanic is faced with a silent engine. It is a case of posing the minimum number of questions from which to deduce the cause of the breakdown. Thus errors are inevitable when diagnosing the cause of the trouble; but the main point is to take account of these errors so as not to go off at a tangent and start checking the thickness of a pane of glass when it is an electric circuit that is at fault! Thus the good mechanic is the man who, with every test, eliminates the maximum number of possible causes, and so on until he puts his finger on the right one. Anyone who has ever had to repair a mechanical apparatus of any kind—car, motor-cycle or bicycle—is familiar with this situation and knows that some people carry out repairs faster than others, in other words that some methods are more efficient than others.

Some people proceed more or less at random, hoping to land on the lucky number as if in a lottery and, of course, they sometimes win. Thus a garage hand whose first guess is that sand is blocking the carburettor may astonish you by setting your car to rights at once. He had one chance in several thousand of being right! Statistically speaking, he was wrong to go straight to this, but he could have been lucky and guessed right. Other people set about the job systematically. They know that they may make mistakes, but they also know how to proceed if they do. One mistake committed, rules out the need for a lot of searching, thus reducing the number of hypotheses to be tested. So the mechanic proceeds, from hypothesis to hypothesis, each time eliminating the maximum number of possible causes of trouble. Naturally he makes mistakes, since he is not able to repair the engine at the first attempt; but he sets to work methodically and systematically, which is more than can be said of his colleague, acting solely on the 'hit or miss' principle—though this is not tantamount to saying that the latter is only groping in the dark, for he is guided by a 'hunch'.

For all this, the 'hunch' of the garage hand who rushes to look for a grain of sand in the engine is not a hypothesis which he is out to test; he is virtually certain he is right, though he has as yet no grounds for his belief. Thus it is not merely the methods he has to be taught, since all his actions stem from a false 'idea'. All teaching systems must take account of these ideas which, though they lead to an unsystematic organization of the data and to unmethodical procedures, are, nevertheless the only means the student possesses for sorting out his knowledge, new and old. This does not mean that the objectives of the sequence will be changed: the goal towards which all the students are directed remains the same, but the routes they take to reach that goal may need to vary in accordance with the ideas which they start off with or pick up on the way. Appropriate methods will be applied, in each case, for dealing with such ideas and correcting them as they become apparent.

This is essentially what Crowder's type of programme proposes to do. Before explaining how this programme is composed, we will give an example which should be considered only an illustration and not a model.

A

In mathematics, the word 'set' denotes something specific.
We shall endeavour, today, to define what this is.
You have already heard this word used, and have used it yourself.
For example:

a set of people, as in 'jet set';
a set of tools—hammer, chisel, pliers, etc.;
a twin set, in ladies' clothing, and so on.

In each of the above cases, the word 'set' is used to denote a collection of several things forming a whole—people, tools or garments.

But there are also many other words which convey the idea of a set:
For example: a team; an association; a troop; a collection, and so on.
And you surely know many others.
All these words convey the idea of several objects, collected together.

But we do not always know precisely what these objects are. With the word 'set' (in the mathematical sense of the term) we do. *Here are two examples*. Which gives the more precise idea of a set (in the mathematical sense of the term)?

- A group of individuals → go on to B.
- The players of the French football team in April 1965 → go on to C.

E

Very good. That is correct.

It is possible to find out *how many* spectators there were at the rugby match France versus Wales, either by counting the number of entrance tickets, or by means of photographs.

We know, in any case, that the stadium contains a limited number of places; also that all the spectators are inside the stadium.

In the case of the Côte d'Azur, the position is different. It is not absolutely clear what area it covers: some people would say it goes as far as Cannes, others as far as Toulon. Thus it is not possible to find out precisely how many people were on holiday on the Côte d'Azur. It is a little vague, as you see.

- Go back to A, and pay more attention to the question you are being asked.

B

You have not thought about it properly!

When we say that a measurement is *precise*, it means that we know the number of units of measurement contained in a certain volume, for instance.

Similarly, the idea of a set is *precise* when we know exactly what this set is composed of, i.e. what objects it comprises.

A 'group' of people may be composed of 10, 50 or 100. We can give no further details; nor do we know what it is that links them together.

On the other hand, everyone knows that the '1965 All-France Football Team' is composed of 11 players, each of whom can be named.

Here are two more examples:

1. The spectators of the France-Wales Rugby match in the stadium on the day of the match.
2. The people on holiday on the Côte d'Azur in the summer of 1966.

Which of these two examples gives us the more precise idea?

- Example 1 → go on to E
- Example 2 → go on to D.

G

Very good.

The set composed of the 'cigarettes in *this* packet of Woodbines' comprises nothing but what it *says*, i.e. the 'cigarettes in this packet of Woodbines'. We do not mention tobacco in order to specify the idea of this set: thus tobacco is not one of the objects of this set.

Do you now understand a little better how a set is defined?

Before going on, go back to C and select the correct answer.

C

That's *very good*. Your answer is perfectly correct.

'The players of the All-France Football Team in April 1965' gives us the *precise idea* of a set.

We can find out precisely who the players composing this team were.

They cannot be confused with any others, and *they alone* compose this set.

The idea of a set is precise when its composition is known exactly.

When, on the other hand, we speak about a 'group of individuals', we do not know either how many people it is composed of—5, 10 or 20—or who these people are. This group is therefore not a set (in the mathematical sense of the term).

Let us remember this: we have the idea of a *set* when its exact composition can be known and is *stated*.

Let us now take another set: 'the set composed of the flowers in this bunch'.

It is both *known* and *stated* what this is composed of.

Do the 'petals of these flowers' form part of this set?

Think carefully before giving your answer.

- Yes → go on to F
- No → go on to I.

D

It is not certain.

It might perhaps be possible to count the number of 'people who were on holiday on the Côte d'Azur in 1966', but, to do so, we should have to know exactly what the Côte d'Azur comprises. We do not know exactly where this region begins and where it ends. Is it composed only of the beaches and the towns lying along the coast between Monaco and Cannes? Or between Monaco and Toulon? Does it also include the towns located inland?

People do not all agree, and have not all, therefore, the same idea of 'the set composed of the people on holiday on the Côte d'Azur in 1966'. As you see, this conception can hardly be a precise one if we are not all talking about the same set.

On the other hand, we can find out exactly who were the 'spectators in the stadium on the occasion of the France-Wales Rugby match'. And we know that only these spectators belong to this particular set. Thus the idea of this set is a more precise one.

Turn back to A and select the correct answer.

I The question was a difficult one, and you have answered it quite correctly. Well done!

When I speak of 'the set composed of the flowers in this bunch', I say clearly this set is composed of the 'flowers in this bunch', that and nothing else. I *have not said* that the set contains the 'petals of these flowers'.

Conclusion: These petals do not form part of the set in question. Let us now take 'the set composed of the chairs in this class-room'. I *say* that it contains the 'chairs in this class-room'.

I do not say that it contains the legs of these chairs or anything else.

Conclusion: 'The set composed of the chairs in our class-room' does not, therefore, contain 'the legs of these chairs'.

We say that:

The chairs in our class-room are *objects*. These objects comprise the set in question.

The legs of these chairs are likewise *objects*. But they do not form part of this set.

Another example: 'The set composed of the bees in this swarm'.
'These bees' are the *objects* of this set.

'The wings of these bees' do not form part of this set because this has not been stated.

Can it be said that the wings of the bees are the *objects* of another set?

- Yes → go on to . . .
- No → go on to . . .

F This will surprise you; but you are wrong!

In the 'set composed of the flowers in this bunch', we *speak* of 'flowers' and not of 'petals'. And the idea is a precise one because we know what it is composed of, 'these flowers' and nothing else.

Similarly, I *say* that the 'set composed of the chairs in this class-room'is composed of 'these chairs' and nothing else. The legs of these chairs are not included in this set because I have not *said* so.

As you see, we must pay great attention to *what we say* when speaking of a set.

When speaking of the set composed of 'the cigarettes in this packet of Woodbines', are we talking of the tobacco?

- Yes → go on to H
- No → go on to G.

H *You are making the same mistake as you did just now!*

Everyone understands perfectly well that you have to have tobacco in order to make cigarettes. But if one is thinking of the manufacture of cigarettes, one *is not talking of sets*. Nor is one doing mathematics, as we are endeavouring to do.

When I *speak* of 'the *set* composed of the cigarettes in this packet of Woodbines', I *say* that this set is composed of the cigarettes in this packet, and nothing else. I have not *said* that this set is composed of tobacco. In the set, as defined in mathematics, the tobacco is not mentioned: it does not form part of this set. *Have you really understood?*

- Think carefully, then turn to G.

Description and method of use

It is clear from this programme extract that pupils are directed along various routes according to the responses they make. There are thus several possible paths; the one taken depends on the answers the students give at each stage, and different students may go different ways. Figure 10 below shows the various stages of which a possible sequence is composed.

The diagram is not as complicated as it looks. Each of the numbered stages represents a part of the sequence, and consists of a completely separate item, as in the case of Skinner's programme. A pupil who gives the correct answer every time proceeds straight on to the end: his progress is shown by the straight line, passing through stages 1, 3, 4, 7, 11, 21, in that order. Another pupil makes mistakes, which lead him along another route, taking him for instance through stages 1, 2, 3, 4, 19, 20, 7, 11, 21; yet another pupil, who makes different mistakes, has to study items 1, 6, 9, 3, 4, 7, 4, 19, 4, 7, 11, 21.

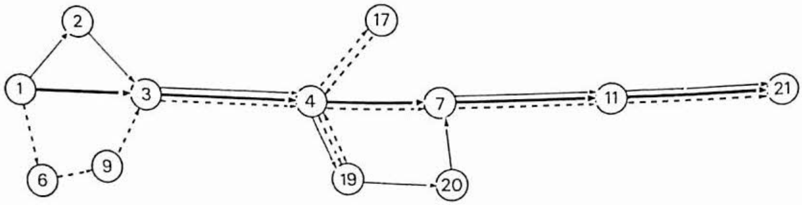


FIG. 10. Stages of a sequence.

It might be amusing to calculate the number of different possible routes, with 35 items, interlinked as shown by the arrows in the diagram.

In any case, it will be seen that each pupil follows only one route in the sequence, although, for some of them, it is as if one and the same lesson was composed of several sequences. It is for this reason that this type of programme is sometimes called a 'polysequential' programme, as opposed to the 'uni-sequential' Skinner-type programme, where all pupils follow the same route. Let us now take a closer look at the items.

Items. These, by and large, comprise the same elements as Skinner's items: information, a question and, in the following item, formulation of a response depending on the response selected. But we see too that the responses differ greatly in their nature and form. Let us take, for example, item 1. The information contained is no longer simple and rudimentary, but of a certain complexity and variety. A question is asked, but the pupil is not required to formulate a response, only to select, from several responses, the one he considers to be correct.[1] And lastly, the item to which the pupil is referred by the choice he makes does more than simply supply the correct response: when a mistake is made, it sometimes even refrains from giving the correct response and, what is more, may even administer a reprimand.

The information is given in larger amounts: it constitutes a whole series of the small units or 'small steps' carefully differentiated by Skinner. Crowder considers that only in this way can the 'ideas' which link together the behavioural elements be brought out. The size of step will thus vary according to the estimated likelihood of a particular idea, whose existence one has previously observed, emerging or being formulated.

The question set is the means whereby one can check that one has estimated correctly. The question no longer forms the basis for prompting pupils to give the correct result: they do have to select the correct answer, but from amongst various others, which are incorrect. Without realizing it, the pupil is led to engage in activity about which he is conscious of nothing but the aim—to select the correct answer from several possible ones. Thus, though the activity of the pupil is solicited, it no longer constitutes the instrument and the reinforcer on which Skinner built up his learning process. On the contrary, with the multiple-choice system, only the final result can be observed, although the very selection of one response rather than another indicates that the pupil must have organized the preceding material on the basis of a certain central idea or strategy. Such, at any rate, is the assumption of the programmer when compiling the set of possible answers.

---

[1] This explains why this type of programme is also called a 'multiple-choice' programme.

As in Skinner's method, the principle of immediate confirmation of results is respected, and the pupil cannot pass on to the text stage until he has checked the correctness of his answer. In fact, the analogy is not complete, since it is no longer a case of the pupil's always having to check that he is right. To some extent this goes against the theory of operant reinforcement. Crowder does not deny this, and admits frankly that his type of sequence makes no claim to a theoretical basis. In order to explain more clearly where the theoretical differences between the two systems lie, let us follow the progress of a pupil working on a Crowder programme.

Say he is at item 1: he is presented first with the information and then with a question, and required to select the response he considers satisfactory. This he does, and is then sent on to another item. There are several possibilities at this juncture:

1. His answer is correct, in which case he is congratulated by some formula confirming the correctness of his choice, ranging from the simple statement, 'That's right!' to some more effusive expression of satisfaction. Some theorists have compiled a whole series of graduated comments, adapted to the quality of the answer and taking account of the pupil's possible reactions.

This comment is the means of reinforcement which, it may be thought, is a misuse of the term. Reinforcement operates on an observable, prompted activity. It is not being applied here simply to the result of the activity, in order to fix the response selected, but rather to the reasoning leading to the selection of that response. The point is that an attempt is also made to reinforce the attendant activity: the pupil is not simply patted on the head, but is also given an explanation of the reasoning leading up to the result obtained, so that he is able to check whether he arrived at the result by the same means. Thus it is here that reinforcement is mainly applied. This point should be stressed, since it is often said that reinforcement is confined to the intital expression of commendation. Subsequently, the pupil can be given further information, followed by a question accompanied by a set of possible answers. But it is also conceivable that this may take the form of another item to which the pupil has been referred.

2. The pupil has given an incorrect answer—one which is wrong, merely incomplete, or downright absurd. In this case, he is sent on to another item, in which he is informed that his

answer was wrong. This information may be conveyed by a number of phrases, perhaps more numerous even than those used for congratulating students on success, ranging from a simple statement of fact to a metaphorical rap on the knuckles with all manner of intermediate formulae. Thus, carelessness or serious mistakes in reasoning are roundly condemned. The sole purpose of allowing mistakes is to eradicate them, so the faulty process of reasoning which led to them is elucidated in order that the pupil may understand where he went wrong, and reach the point where he can himself see that his answer was wrong and put it right.

Thus, with this attitude to error, a veritable remedial system is built into the learning process. The pupil who commits an error is separated from his fellows and given individual treatment. He may simply have gaps in his knowledge, or he may have forgotten. The correction items to which he is referred thus serve several purposes: first to correct the student and put him straight; but also to supply additional information, refresh his memory of ground previously covered, or even give him a 'breather' before resuming the subject. And for each of these purposes, a special route has been devised. This is known as a 'branching' or branched programme, as opposed to Skinner's 'linear' programme.

Branching programmes and the individualization of learning

Students obviously progress at their own pace, so that the method is individualized as regards speed, as with linear programming.

At the same time students progress according to the way in which each one grasps the material taught. The sequence is so designed that students' reactions are tested at every stage and adaptations made accordingly, making the programme both depend on and influence the attitude of the student. Since both the content and the method of presentation are adapted to the student, this type of programme is called 'intrinsic', whereas the term applied to the linear type of programme is 'extrinsic'.

It would, however, be raising false hopes not to mention that the adaptability of these programmes is subject to certain limitations and is not always as complete as we suggested above. Adaptability depends essentially on the nature of the aid or device used. In the case of programmes based on textbooks or workbooks, for instance, items cannot always be arranged in order, since each sequence comprises several superimposed routes; also, it is essential to avoid placing the answer item next to the question item, otherwise the student will be able to look at the correct (or incorrect) answer before selecting his own. This is why the items are deliberately arranged out of order, and we say such a book is 'scrambled'. When a mistake is made, it is corrected immediately. The system should, in principle, be such as not only to correct the mistake, but also to go back over the steps leading to that mistake, and any previous mistakes as well. In practice, this would involve devising routes which do not coincide or include no common sections, even though there are many elements common to them all. This would make the sequence too large and unwieldy. In other words, the restrictions imposed by the nature of the aid or device we are using oblige us to plan routes which, though different, have nevertheless many common sections. The only way round these restrictions is to use highly perfected electronic devices, particularly computers, where the volume of the information to be fed in is of little importance, since retrieval is both simple and rapid.

With branching programmes, the aid or device used is important since it determines, in some measure, the type of instruction adopted.

Should linear and branching programmes be compared?

This question inevitably arises, and we must expect to be asked to discuss the respective merits and drawbacks of the two. This revives the old quarrel which set the Skinnerians against the Crowderites until they realized that they were often talking about different things: the former were attacking on theoretical grounds while the latter were defending themselves on practical grounds, and vice versa. It was at this point that convinced supporters of the practical approach suggested settling the dispute by an experiment, consisting of assembling and arranging sample lessons and then comparing the results obtained by the two methods.

No significant difference of efficiency was noted. And this 'tie' satisfied many people by justifying the existence of both factions. The only drawback is that, even if the results had been different, this would have been no argument in favour of the system which came out best.

As regards method, it is a truism to say that things which are not comparable should not be compared; and, as we have stressed, the fact of being based on two wholly different conceptions of error leads to such wide divergences between the learning methods proposed by these two types of programme that it is difficult to set them one against the other.

It might be concluded from the above that the choice of one

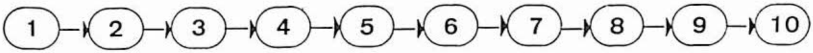


FIG. 11. Linear sequence.

or other method is merely a matter of personal preference. However, the fact remains that over eight out of every ten courses produced are linear. There is good reason to suppose this is due to the fact that linear courses are readily believed to be easier to organize, and to use simpler aids. This may explain to some extent why they are preferred.

Some guidance in the matter can be obtained from students' reactions: they find both *only* linear or *only* branching programmes in the long run tiring and monotonous. This suggests to us that we should opt for a combination of the two, using both alternately in order to achieve a certain variety. The desire to exploit the respective advantages of both systems has led teachers and research workers to propose various different combinations of the two. The best known of these is what is known as 'skip-branching'.

SKIP-BRANCHING

This method was presented by Leiris. It is illustrated by the diagram above, which represents a linear sequence (Fig. 11).

What Leiris did was to devise certain variations on the linear sequence: by accelerating or slowing down the rate of progress, it is possible to match more clearly the pace of all types of student—the impatient, the cautious, and so on. Various possibilities can be provided: (a) a faster route for the quick student, impatient to forge ahead (Fig. 12); (b) a slower route for the student who feels he is being hurried too much (Fig. 13); finally, (c) a loop route to allow the student who is out of his depth because he overestimated his speed to retrace his steps (Fig. 14).

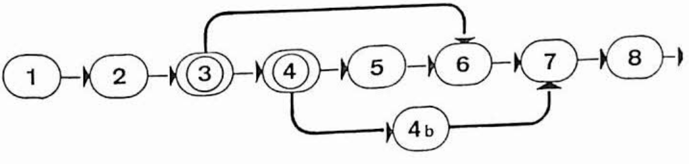


FIG. 12. Express routes.

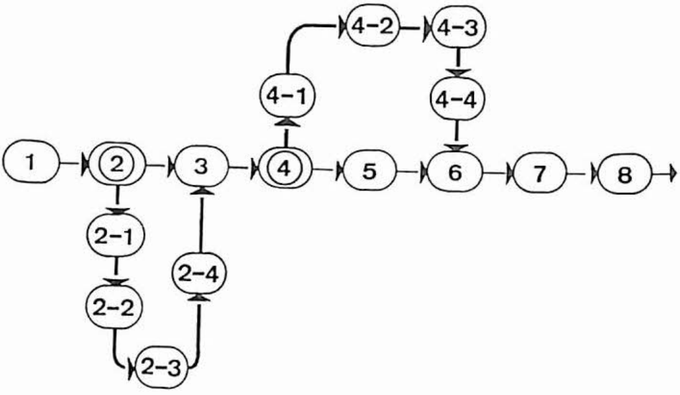


FIG. 13. Peaceful byways.

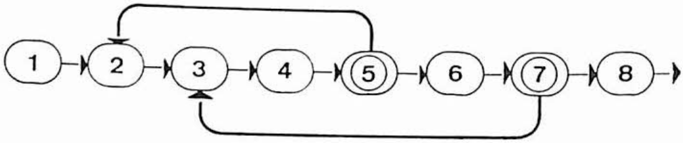


FIG. 14. 'I was in too much of a hurry.'

Variants of this kind can obviously be devised at leisure. But we may ask whether sequences such as these differ from branching sequences of the Crowder type. When the aid used is a book, the material will have to be scrambled, since one and the same book proposes various alternative routes. But this is the only real resemblance between a skip-branching system and a branching sequence. Skip-branching takes no account of error, nor does it propose any special form of learning for the student who makes an error. The 'jumps' make the pace adjustable, since the lesson can be adapted to the speed of the individual student who no longer has to slow down to keep pace with the other students following the same route as he is. The aim of those who have invented variants to both main types of programme has almost always been to make the programmed course more adaptable to the needs of the individual student.

Other variants are also possible. They consist of combining, in one and the same sequence, two or three of the models described. Thus there is clearly plenty of choice and there are many different possible combinations. Only the fact that the sequence devised is bound to be of great complexity inclines us to limit the amount of inventiveness expended on the subject before a complicated solution is adopted.

CONCLUSIONS

There are numerous types of programme. This proves that Skinner's model and the underlying theory do not satisfy everyone. Nevertheless, to ask teachers to make a comparison would certainly involve them in fruitless disputes. Many of the conflicting arguments fall away as soon as one actually gets down to writing programmes.

It becomes clear, when composing the sequences, that the theoretical aims or the prospects held out by the various types of programme are one thing, the techniques required for their realization quite another. It would be a mistake, however, to use existing difficulties or preferences as a pretext for deciding that linear—or branching—programmes are better before even attempting to produce any.

REFERENCES

1. SKINNER, Burrhus F. *The technology of teaching*, p. 40. New York, Appleton-Century-Crofts, 1968.
2. CROWDER, N. Automatic tutoring by intrinsic programming. In: Arthur A. Lumsdaine and Robert Glaser (eds.), *Teaching machines and programmed learning*. Vol. I: *A source book*, p. 286-98. Washington, D.C., National Education Association of the United States, Department of Audio-visual Instruction, 1961-65. 2 vols.

CHAPTER III

TECHNIQUES FOR ELABORATING PROGRAMMED COURSES

INTRODUCTION

Having looked at the history of programmed instruction, its theoretical foundations and the types of programme, an account of its techniques will serve as introduction to the practical phase, during which teachers will be asked to devise their own sequences and then try them out with pupils. When told this is what they are going to be asked to do, teachers may well experience some alarm. The theory seems so rigorous, and the programme types seem so well defined that they might feel they need many years' experience and considerable background knowledge before moving on to actual programming.

There is in fact no need for alarm. The complexity of these techniques and procedures is only apparent. If we do run into difficulties in applying them, we shall soon see that these arise not from the manner of their application, but from such factors as the material to be taught, the aid or device chosen, the type of pupil—all problems which such techniques are often expected to solve, but which it is not their job to solve. Yet experience has shown that there is a great temptation to imagine that the difficulties are over, and that one's teaching is scientific, just because techniques are to be used to elaborate it. We shall probably have to struggle against this illusion, since it gives false confidence and conceals the real teaching problems. For this reason we shall constantly be concerned to direct attention towards such problems rather than to give a comprehensive description of all the techniques involved.

There are other reasons which justify this approach, reasons which teacher-educators will easily appreciate:

Descriptions of these techniques are already available in very good textbooks and articles. There is therefore no point in repeating them [1];

A mere description of the techniques will not be enough for teachers. It may well lay them open to unfortunate miscalculations when they come to apply them. For the more intellectually satisfying these techniques may seem on first acquaintance, the more at sea their subsequent application is liable to leave the teacher, with no notion of what has caused the difficulties which have arisen. In addition there is a danger of more serious repercussions if teachers are merely supplied with lesson-making techniques in the same way as an industrial engineering school supplies its pupils with techniques for making a manufactured product. The strict rules which have to be obeyed, the set order in which operations have to be carried out, the sanction conferred by testing, the ease with which the impression can be conveyed that such techniques will solve the problems they encounter—all this is going to leave teachers either fully convinced or completely sceptical.

It will be no surprise, then, if the attitudes we condemned at the beginning make a reappearance, supported by a new set of rationalizations. Some will be based on the feeling that the application of techniques is a panacea, others will light on the imperfections of those techniques as a pretext for rejecting them all *en bloc*, and programmed instruction with them. Both attitudes show little understanding of the value of techniques and a poor appreciation of their real advantages. But perhaps the worst feature of the situation is that such attitudes will also have nurtured a distrust of all projects for the reform of teaching.

If such a crystallization of the initial reactions is to be avoided, constant account must be taken of any questions teachers raise. When presenting these techniques, the expert must not hesitate to stress their shortcomings and imperfections. When criticisms are formulated or presented, he should pick out their positive aspects and focus the main attention on problems that affect teaching practice.

With this in view, the many different techniques in use will be divided into two types: first those which, directly or indirectly can be traced back to Skinner's original inspiration; secondly those which, while drawing on the tests and findings of the first group, have broken with that tradition in order to go further. There are many conflicts between the two groups, but there is little to be learned from attempting to follow the debate. What is more important is its outcome. For the rival theories give rise to controversy and as they come into conflict, they are challenged, revised and replaced. Programmed instruction is becoming diversified, inspiring new inventions and finding new applications. Its development continues amid a growing profusion of doctrines, techniques, refinements and variants. It is important to realize this if we are to understand the part such techniques should play and obtain a true picture of them. The search for improvements is the result of practising such techniques, putting them to the test of actual use. This means it would be very difficult to trace a single line of evolution through the developments to which such techniques have given rise, so much does their inspiration vary.

We draw attention to this diversity as a warning: any classification is partially arbitrary, any comparison may be fallacious. For this reason it is pointless to judge one technique in terms of another, and call any of them good or bad. Only by considering them and applying them in a critical spirit can we assess what is valid in each proposal. This will give us a whole range of alternatives between which we will choose according to the actual teaching requirements.

Note. Probably the teacher-educator will find this procedure unusual in the sense that it seems very often to sidetrack the exposition, and to make for many preliminaries. The preliminaries simply consist of warnings and advice on what seems the most suitable form in which to describe the techniques to teachers. It is very difficult to give a coherent and ordered picture of what programmed instruction is today. We cannot easily find our way through this maze of proliferating innovations, procedures and doctrines as long as we attempt to proceed inductively, from the myriad particular techniques to a clear over-all picture of programmed instruction in general.

However, the picture does have a unity. It is possible to understand what lies behind the development of programmed instruction by emphasizing the *teacher's* requirements. Judicious use of programming techniques enables them to be spelt out more clearly, which in turn suggests further research in which other techniques will prove necessary.

This is the main reason why we have decided to draw attention to these requirements on every possible occasion, especially when we come across imperfections in programming. In this way we invite the teacher-educator to offer his students, not that perfect mastery which an engineer achieves, but practice in a type of teaching which gives them a new conception of teaching and a new approach to it.

We shall call the first type of technique 'traditional', the second 'new', keeping in mind that this is only a convenient distinction which is not meant to imply that one type is better or more promising than the other.

SECTION I. THE 'TRADITIONAL' TECHNIQUES

These are fairly numerous, particularly if we count the variants to which many of them have given rise. But all have in common some stages or phases in the elaboration of a sequence: this makes description much easier. Moreover we shall give a detailed description only of those which are in most common use. The only novel feature about our description of them is our above-mentioned concern with teaching requirements, since this goes beyond what is strictly technical.

Table 1 gives a list of the best-known 'traditional' techniques; we shall be concentrating particularly on numbers 2, 3 and 4.

The reason we gave earlier for using the name 'traditional' was that these techniques are in the Skinnerian tradition: they are in this tradition in the sense that, whether in principle or *de facto*, they conform to the hypothesis of the 'black box'. This means they analyse the processes of learning or teaching in the manner of behaviourist psychology, i.e. in terms of behaviour.

Table 2 shows the main stages in constructing a sequence. A plus sign marks those which are common to all the techniques listed in Table 1. The lines joining columns indicate other relations linking certain of these techniques. Thus it can be seen that behavioural analysis (column 3) and semantic analysis (column 6) have great similarities from the point of view of writing the sequence.

Table 1. List of techniques

Name	Inventor
1. Ruleg	Homme and Glaser
2. DAVIES' MATRIX	Davies
3. BEHAVIOURAL ANALYSIS (Mechner)	Le Xuan
4. MATHETICS	Gilbert
5. Graphs	
6. Semantic analysis	

TABLE 2. Stages in constructing a sequence

Stage	Name	Techniques[1]					
		1	2	3	4	5	6
a	Defining the objectives (content; population)	+	+	+	+	+	+
b	Tests (pre-tests; post-tests)	+	+	+	+	+	+
c	Arranging the subject-matter in logical order	—	—				
d	Writing the sequence:						
	Types of programme	—	—	—	—	—	
	Aids and devices			—	—	—	—
e	Experimental testing; validation	+	+	+	+	+	+

[1] cf. Table 1.

This table shows clearly what constitutes the main family resemblance between the techniques: all begin by defining their objectives in an identical way, and then call for the preparation of tests. Although their ways subsequently divide, they come together once more at the experimentation and validation stage. In other words, we shall say that their aims, and the means of checking that those aims are achieved, are conceived in the same spirit and in roughly the same form.

We shall now consider the first stage and discuss how one can get teachers to understand its nature and master its methods.

DEFINING THE OBJECTIVES

Let us not forget the point we have reached. We know what laws of learning we have to bring into play, and we know the way in which they apply in a sequence. We now want to programme one such sequence. What and who will it teach?

When we have answered these two questions, we shall have determined the two types of objectives which we shall then have to define. These are, first, the content or subject-matter to be taught and, secondly, the population—the pupils for whom such instruction is intended.

According to the experts, defining the two presents no problem: such definitions should simply be expressed in terms of behaviour. This means that they have to be framed in terms of 'know-how' and not of mere 'knowledge'. Know-how is manifest in activity, the processes and results of which can be observed. It can thus be used for reinforcement and can be subjected to testing.

We can illustrate this by giving an example of what should not be done. In the 'Syllabuses and Instructions' issued for the State education system in France, some of the aims to be achieved in the penultimate primary grade are defined in the following way:

In this class the teacher can start methodical grammar teaching.

But:

1. . . .

2. He will avoid asking questions which are beyond the children's comprehension.

3. He will have pupils memorize *the conjugational paradigms and syntactic and other rules (with accompanying examples), thus* fixing *and* imprinting *the knowledge in their minds* [2].

The teacher is advised to be 'methodical', and there is talk of 'knowledge' which is to be 'fixed' and 'imprinted' in the mind. The text goes on to tell us what this knowledge is in the form of a list of headings: the verb—the concepts of mood, voice, etc. . . . Never at any stage is this expressed in terms of know-how. We are not told what it means to have the *concept* of mood. The text is equally obscure about how knowledge of it is to be conveyed. Where there is no known means of observing, still less of checking, whether the objectives have been attained, those objectives cannot be described in other than abstract terms. This makes it impossible to explain the way in which such knowledge will be acquired.

All the usual abstract words (know, realize, understand, etc.) carry the mark of a type of psychology which behaviourism has condemned as being unscientific. What they refer to is too vague to be subjected to experiment or to the effects of operant reinforcement. In these circumstances, the nature of what one intends to teach is ill defined, and one's aims are imprecise and intuitive.

A correct definition, then, must enable the behaviour of the pupil to be subjected to the control of reinforcement. Defining the subject-matter seems to present no difficulties. It will be described in behavioural terms, i.e. as a set of clearly determined activities which the pupil will be able to perform at the end of his learning process. It can also be said that the aim here is some 'terminal' or 'final' behaviour. But we must beware of misinterpreting the words: the point Z which one wishes the pupil to attain is called *terminal* or *final*, as if it were the point of arrival as distinct from the trail which leads to it. This is not so: the final behaviour is also, in some sense, a summing-up of the whole learning process, which can indeed be reconstructed in reverse order from it, passing from one stage to the next.

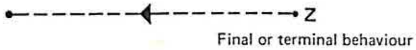


FIG. 15.

It is as if we had begun by determining the results to be achieved, and had taken that as a point of departure for describing the path representing the learning process, a path which obviously the pupil takes in the opposite direction (see Fig. 15).

Since we have seen what should be done and what should be avoided, it remains to be determined *how* this is achieved in the case of the subject-matter of instruction. But first we must consider what comprises a 'behavioural' definition of the population. This point must be emphasized, because misinterpretations are common, the adjective 'behavioural' being falsely applied to definitions which have nothing behavioural about them. In no case should we be satisfied with specifying the pupil population by its IQ, its membership of a class in school (the preparatory class, penultimate primary class, etc.) or by some level of attainment supposedly indicated beyond dispute by paper qualifications.

Such specification is too general and does not give a clear picture of the pupil. His IQ is an indication of capabilities which are vague in their relationship to the behaviour patterns to be instilled. If the lesson is on how to reassemble a carburettor, the teacher might have two pupils of identical IQ. If one has already dismantled internal combustion engines, while the other has never seen any, the two cannot be considered in the same light: one of them potentially possesses types of know-how on which the teacher can rely, whereas the other must be made to acquire them. The learning process will not be the same. Had the teacher relied solely on information conveyed by the IQ, however, both would have received identical treatment. The same applies when reliance is placed on the fact that pupils belong to one class or another. People claim to know what pupils have learned by looking at their study syllabuses for the preceding years. If this particular pupil is in the last year of primary school, then in arithmetic he knows everything he has been taught up to the penultimate primary class. Everyone will realize what a false impression of the pupil is given by such a method. As for paper qualifications, they give an even falser impression, if this is possible. At school they are awarded on a mark which is averaged over several subjects. It is by no means sure that any given pupil will have obtained a pass mark in the subject in which he is now to be taught something new.

Since such indicators are so unreliable, it is impossible to tell on this basis whether reinforcement is being rightly and relevantly applied. This means teachers can have no confidence in being able to evaluate the learning process, since they do not know on what 'reinforcing contingencies' to operate.

The 'behavioural' definition of the population should comprise such information as to enable reinforcing contingencies to be planned. Let us recall what this means by returning to Skinner's pigeons. These were free to do as they wished. In their cage they could make any movements and take any action to which their environment prompted them. Of all the stimuli received which occasioned responses, there had to be reinforcement of the appropriate ones—those which involved the repetition of pecking on the selected circle. The environment can vary in complexity, and can entail very many factors. In a laboratory situation, these can partially be selected by the conditions of the experiment. The experimenter acts—through reinforcement—on those which are actually being taught. In principle the pigeon's situation is similar to that of the pupil, the only difference being that the factors capable of bearing on the latter's behaviour are much more numerous and it is impossible to use laboratory methods for reducing their number and selecting them. The greater the number of factors which can act on a subject, the greater is the element of chance entering into the effect that can be produced on particular factors by means of operant reinforcement. The random element increases proportionately. However, it is precisely in the kind of complex environment where such an element manifests itself that the pupil must be made to learn a particular behaviour.

The components of the pupil's environment and the situation to which he reacts are of such complexity that they defy any full, scientific analysis. The full range of such stimuli constitutes the reinforcing contingencies among which the learning process will operate in order to apply the laws of reinforcement [3]. If we follow Skinner in relying on these lessons to be learnt from experiments, we see that for any population we should first know the stimuli to which they react in a given environment. The environment may comprise linguistic, technical, manual or other competences. We should know whether these can be catalogued, and whether the relative importance of such factors can be measured, so that one can be quite certain to which of them the laws of reinforcement should be applied.

This is possible in a laboratory, where it is the learning process that is under study. It is no longer possible when we move on from learning to teaching. Skinner willingly admits this when he quotes William James in the following passage:

More than sixty years ago, in his Talks to Teachers on Psychology, *William James said: 'You make a great, a very great mistake, if you think that psychology, being the science of the mind's laws, is something from which you can deduce definite programs and schemes and methods of instruction for immediate schoolroom use. Psychology is a science, and teaching is an art; and sciences never generate arts directly out of themselves. An intermediary inventive mind must make the application, by using its originality'* [4].

. . . .

A special branch of psychology, the so-called experimental analysis of behavior, has produced if not an art at least a technology of teaching from which one can indeed deduce [our emphasis] *programs and schemes and methods of instruction* [5].

While it may be difficult to compete with science, we should be able to go further than can art. This will be achieved partly by eliminating the empirical and intuitive element from the definition of population. For this purpose we shall endeavour to collect together, select and then define the characteristics of the pupils on the level of behaviour, the 'operational' level. Here, 'operational' should be distinguished from 'operative', the former being used here in the same sense as behavioural. What is meant is an observable activity or act which can be checked either directly or by its results. The terminology of programmed instruction is marked by behaviourism. 'Operative' is a word which sounds quite alien to behaviourist modes of thought. We are here dealing with what is 'relative to operations'; *we shall give the name operations to those internalized or internalizable actions which are reversible and co-ordinated as total structures* [6].

This means that we shall draw up a list of pupils' know-how, by means of the appropriate inquiries or questionnaires. What we are going to consider, therefore, is actual pupils, defined by what they know how to *do*. We shall therefore list all the stimuli to which they are capable of responding in an adequate manner. For example, if we put a question to them using a given word, does their reply correspond to the meaning of the word? If a very long addition entails 'carrying over' numbers above 10 or 100, can they do it?

But a pupil's items of know-how are innumerable. It is inconceivable that they can be counted for even a single subject; it is quite pointless to try to do it for many. To circumscribe our inquiry, we shall use the point Z (Fig. 16 (a)), that of the terminal behaviour, in other words that of the subject it has been decided to teach. Depending on what has to be already known before this can be learnt, we shall thus attempt to define a certain 'initial' behaviour which is only part of the pupils' potential know-how.

Point A, which is represented here by everything inside the thick line, stands for the 'initial' behaviour. We see that it expresses only part of the 'contingencies' on which it would be possible to rely. In order to choose this part, reference has been made to point Z, the final behaviour. Thus what determines the point of departure is the target one wishes to reach.

To summarize: in order to define that part of the objectives denoted by the word population, that is point A, the programmer has to select, from among those patterns of behaviour already acquired, the ones he can use as reliable reinforcing contingencies to attain point Z—that is to construct the final behaviour. The essential task, then, is to list all the contingencies, or items of know-how, on the basis of which it is possible to work out a plan for reinforcement which will lead pupils to the end of the learning process.

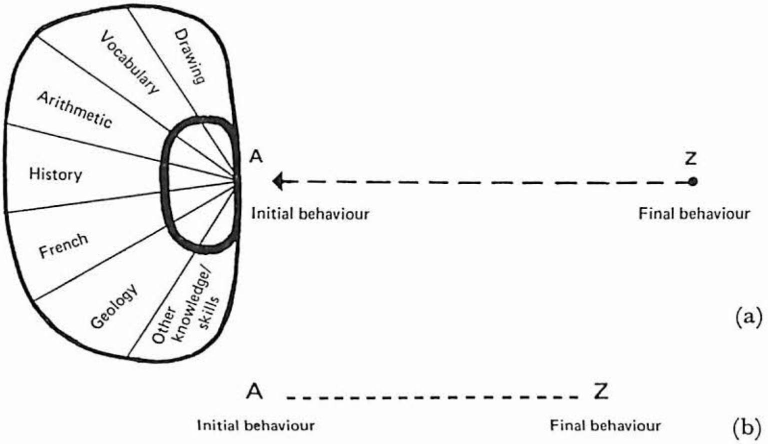


Fig. 16.

The elaboration of the sequence will, in fact, consist in working out this plan from point A to point Z, from the initial behaviour up to the final behaviour (Fig. 16 (b)).

Procedures for the behavioural definition of objectives

Now that so much emphasis has been placed on the reasons for such a definition, there is going to be some disappointment at the small number of procedures by which it can be arrived at. Properly speaking, there are no such procedures, only formulae and stratagems, the usefulness of which will depend on the ingenuity shown by whoever is applying them. This is true of both types of objective which we have distinguished.

The subject-matter of instruction. Let us imagine that a group of teachers have chosen to give a programmed geography lesson with the title 'Continental Waters and their Drainage'. The lesson is intended for children of the first year of secondary school.[1]

The job of the discussion leader will be to get the group to define precisely what it wants pupils to have learnt by the end of the lesson. Invariably, whenever practical work is first started, there are immediately innumerable difficulties. As the title implies, the subject can be envisaged in many different ways: descriptive, explanatory, hydrographic, ecological, etc. It can be considered in greater or lesser depth, depending on whether or not more than one approach is adopted. There are, in other words, many different levels of exposition, from a simple map to a thesis which expounds theories. One difficulty the group will quickly encounter is that it has no very clear idea what to include under the title above. But this is not the only difficulty. If one asks the members of the group what they want their pupils to know after the lesson, they will say, for example: they must know what a river is, a river-basin, a hydrographic network, the régime of a river, etc. The trouble is that such formulations are not 'operational': they are not expressed in terms of know-how or behaviour.

The ensuing debate is usually vigorous and ends with the subject-matter of instruction being called into question. As we know only too well, once the existing system is challenged on this point, the process does not usually stop there. This is of course a phenomenon of some interest, but it can easily get bogged down in discussion regarding the aims of education, the educational system and similar generalities. The discussion should therefore be brought back to the point: the subject and subject-matter selected.

---

[1] This is the title of a sequence written at Brazzaville (ENSAC) in July 1969. We use it here simply as a theme in our exposition.

But in this more limited field, a new debate arises: the very conception of the subject, its doctrine or its principles are challenged with many different arguments. The geographers' group clashes as it divides up into disciples of rival schools; the grammarians split into prescriptive and descriptive linguists, the mathematicians splinter into, on the one side, the advocates of 'new' mathematics, and on the other its opponents, etc. Thus the attempt to define objectives gives rise to a new Quarrel of the Ancients and Moderns. We have often observed that the most valuable feature of this debate is that it throws light on the gaps in teachers' education of which they themselves are painfully aware. They want to be surrounded with textbooks, dictionaries, specialized books, etc. They seek a dialogue among themselves based on a better knowledge of the subject they teach. The instructor in programmed instruction will perhaps momentarily regret this diversion; but on second thoughts his reaction will be less critical.

Very often another phenomenon crops up in attempting to define together the subject-matter of instruction. When speaking of a concept whose content they have been asked to indicate (the régime of a river, its drainage area, etc.), the teachers give a definition of it by reference to the way their pupils understand the concept. '*Water?* No, you'll never get a child of 12 to understand what you're driving at.' This reaction cannot be ignored, but in fact it is often the expression of an unwillingness to re-think the subject taught [7].

Reflection on content and on methods (the latter with reference to pupils) should be kept separate. One way of avoiding interference between them which is found to work in practice is to prompt the group to define its subject *without regard to the intended population*. This method is obviously a gamble, but it enables attention to be focused exclusively on the subject selected and to leave aside the question of what pupils may understand of the 'régime of a river'. The intention is to get teachers away from teaching preoccupations and, by thus taking them outside their normal world, to bring them face to face with the subject they teach. The effort required to achieve this break with daily work habits may take up several group working sessions. This should not be deemed a waste of time, particularly if it enables everyone to agree on the use of words and attach the same meanings to the concepts they denote.

It might well be noted that this procedure does not provide *criteria* by which a behavioural definition of the selected subject can be established. And it is no use looking to the programmed instruction expert for criteria: they do not exist. We have referred above (p. 84) to what Skinner, quoting William James, said regarding science and art: the expert is in point of fact between the two, knowing on the basis of scientific data what he must *stop doing*, but also perplexed, as he moves on to apply such data, to know what *he should do*. The expected criteria have not been perfected, and we must draw instead on all the resources of *art*. The main such resource is team-work such as we recommended above.

If we are to describe the method more specifically, we can only offer recommendations, advice and examples, thus guarding against some of the obvious dangers. Experience will show more clearly how things should be done and what should be avoided. Meanwhile an effort must be made to define in terms of activities what pupils should know at the end of the programmed course: for example, being able to write a plural 's' at the end of one word or another. For each such activity it must be possible to see whether the concept, task or movement in question corresponds exactly to what the pupil is to learn; this will be checked by means of tests, which we shall consider in a moment.

Much similar advice could be given, but it would not make things much clearer. The important idea is that of testing, and this should be the main guide-line. If I decide that the régime of a river is to be defined in a way which I call *a*, the pupil will have understood if he knows how to 'manipulate' definition *a* in the cases put before him, knows how to 'formulate' it exactly, and if necessary how to 're-explain' it. It is then necessary to decide what we must test: 'manipulate', 'formulate' or 're-explain', or some other activity? This must be decided with maximum precision, keeping in mind that it is the outward expression of such activity which must be observed and tested.

For the purposes of our subject 'Continental Waters and their Drainage', shall we teach the pupils: verbal definitions (e.g. the definitions of river, drainage basin, régime, etc.), a description of the Congo or the Nile or some other river, or more general notions of ecology? And if these are necessary, how are we to convey the connexion between the régime of a river and the climate of its catchment area? Or to memorize information such as: the source of the river, its length, its tributaries, etc.? To reproduce diagrams and situate them on a map, etc.?

Whatever the activity, we must know how can it be set out so that it can be tested. The only guide here is to think of the end sought and the fact that others should be able to check that it has been achieved. This seems little to ask, but it encompasses the whole problem.

Population. Procedures for defining population have not been formulated with any better precision. If our group of geographers has decided to programme a sequence of lessons on continental waters, and is asked to specify the intended pupils, we will see how strong a tendency there is to describe them in the terms mentioned above: by class, IQ, paper qualifications, etc. But defining the population is objective No. 2, and we turn to it only after having considered the subject-matter in its own right. The situation, then, is as follows: the teachers have immersed themselves in textbooks, reviews, etc., to bring their definitions up to date, and provide themselves with a common language on the subject they want to programme. This was the inevitable mutual refresher course on their subject which had nothing to do with their potential pupils. When they defined what they wanted their pupils to learn of the subject, they made a choice: under the heading of continental waters, they listed a number of items of know-how which, *for them*, covered this concept. They then selected those items which, of the full set, should be acquired by the pupils through the programmed lesson. These items will comprise the concept of continental waters as far as the *pupils* are concerned. Figure 17 (a) is a caricature of the situation, without being all that much of an exaggeration. You do not teach all you know!

After much discussion, invective and a little art, let us say that we have defined the subject-matter to be taught, our point Z which pupils must reach. We must still fix point A, the one at which we pick up pupils before launching them on the study

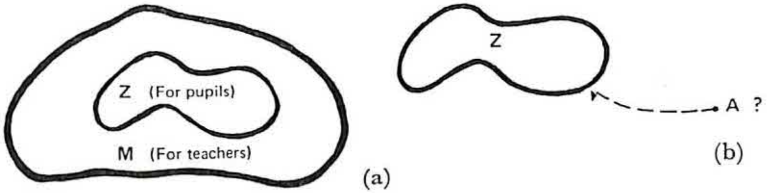


FIG. 17. Continental waters.

of the sequence (Fig. 17 (b)). As we have said above, what we are endeavouring to determine is not the full extent of their know-how, for this would be too vast and complex a task for any science to undertake. So once again we go back to art, to find the 'reinforcing contingencies' on which to operate. Let us be clear, even at the risk of being repetitive: in principle, any behaviour of which a subject is capable may constitute the full set of contingencies on which the reinforcements will act. But we still have to distinguish between them and make an inventory of them before we can act on them relevantly. With a human subject, this is impossible because of the variety of such contingencies. This is why, from the outset, we single out a certain number which are closest to the subject-matter.

In principle, all we have to do is to identify some existing pattern of behaviour, and then, using the procedures of the learning process, we can graft on to it new patterns of behaviour. In fact, we shall take into consideration only a limited number of these patterns of behaviour, and the result of this selection is that we can no longer be sure that the pupils in question have acquired them (Fig. 18). This will have to be checked, and that is the aim of the pre-test to which we shall return below. This pre-test will enable us to determine the characteristics of the population. We shall see later how this is done.

If we are writing a branching sequence, one further task must be carried out at the same time as the objectives are defined. We accept that mistakes will be made, and that if the learning process is to be fully effective allowance must be made for such mistakes. Therefore we have to decide what these mistakes are in order to deal with them as the sequence advances. They have to be known before we start writing the sequence, since the sequence has to identify them, give pupils the opportunity to make them and then has to correct them; all these functions necessarily form part of the objectives.

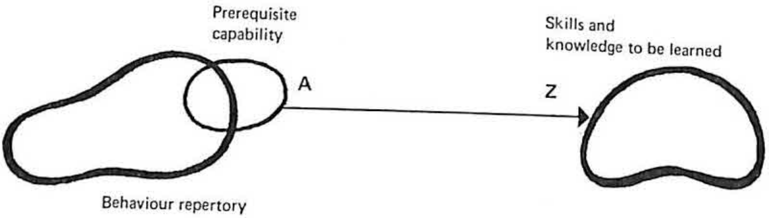


FIG. 18.

In order to list the usual mistakes, we shall find that a whole process of investigation is necessary *before the programme is written.* Stress must be laid on the fact that these investigations must be undertaken from the outset. This is seldom brought out, the techniques for constructing sequences being presented as if they were unaffected by the type of programme adopted. But if the branching sequence is to diagnose and treat mistakes properly, it must also provide the means of recognizing them. This being so, the preliminary investigations must not only identify the mistakes, but must also yield a description of them in such terms that they can be recognized.

Everyone has his own idea of the mistakes which pupils commit, of how serious they are and what causes them. But there are no serious studies, and we have hardly any means of detection and analysis by which mistakes can be classified. For the most part, then, it still remains to devise tools for investigation in this field.

However, in the absence of tried techniques, we can take the same approach as we did in relation to the subject-matter of instruction. There we advocated an effort to impose some form which would render observation and checking possible. Admittedly this is a very vague recommendation, and it is hard to imagine how it can be applied. But the effort required is not fruitless if we observe to what extent the repetition of the same mistakes by pupils brings about a type of fatalism in teachers, which makes them content with perfunctory, often facile explanations. It is surely worth grasping the chance of finding some means of getting away from this system of explanation, which favours a perennial crop of the same mistakes.

When we attempt this, we will certainly come to speak in clearer terms about the mistakes which arise in connexion with 'continental waters', for example; and we shall try to think of a way of teaching the subject which will bring out such mistakes. Teaching a pupil not to make a mistake gives a teacher pleasure and so does correcting a mistake; it will surely give more pleasure if he sees the mistake crop up just when he planned it should, and can deal with it almost as an expected friend.

Remarks. If the reader reviews the techniques recommended during this first stage of the definition of objectives, he will probably feel some disillusionment: what a gap separates the strict requirements of theory from the gropings of practice!

The empirical nature of the processes is incontestable. We have warned the teacher-educator and user that we would not hesitate to show this empiricism at work in practice. And at this stage we are only at the beginning: the empirical element will become vastly more important later. This is enough to prompt serious criticisms. What criteria have we been given which enable us to assert that one definition rather than another is behavioural?

Those already familiar with programmed instruction will certainly feel some consternation at finding such doubts expressed just as they felt a scientific definition of their objectives could be given in terms of behavioural analysis. If they have written programmes, they may well think that by thus questioning the techniques of writing such programmes we are also questioning their work. This would be to mistake the nature of empiricism, which, even if it affords no certain rules or norms for constructing a sequence, leaves considerable scope to art. Whatever imperfections there may be in the method, art will find means of remedying them.

Group reflection, a 'think-in' among a small number of people, on a subject chosen by all of them, seems the best way of achieving this new approach required by the technology of programming. Team work and group work are not magic formulae. Nevertheless, the instructor can use them to provoke questions, to reply to these when he can, and to subject himself to the test of experiments commented on by all present. He should not neglect to use these favourable opportunities, however, because they are likely to be almost the last to come his way.

During the *analysis of objectives*, the teachers give the curricula in language, mathematics, and so on, a thorough questioning. Over against the attempt to define the objectives of a specific teaching assignment, relating to a particular subject, they evoke the 'aims of education', by which they mean the type of education that an educational system must offer a child as preparation for life in society. This is a legitimate concern, because it is inevitable that people will relate a specific objective to a general aim. Nevertheless, the discussion of final aims has nothing to do with the techniques of programmed instruction. By the time these techniques are applied, it is assumed that such questions have been settled and the necessary policy decisions made.

In fact everything happens quite differently. New aims are rarely defined other than by reference to the new techniques (be it programmed instruction or the use of audio-visual aids) by which they could be realized. It is these technical innovations which give us the opportunity to reconsider the aims of education, which everyone agrees needs renewing. In other words, the technology of programmed instruction, which in theory assumes that the problem of the aims of education is already solved, in practice raises this problem, and poses it more acutely.

For we wish to consider the pupils as they are, and to go on from there to teach them something. Questions of *how* and *why* have no bearing on programmed instruction as such, yet they will be posed by teachers as soon as they are introduced to such instruction. We feel it pointless to minimize such difficulties, since the presentation of a new technique of instruction inevitably gives rise to further reflection on the aims of education. We cannot call this a waste of time, especially if the purpose is to end up with a properly tested sequence. While obviously questions of aims must be allowed to come up, discussion of them should not be allowed to go on for ever.

Similarly, when it has been decided to construct a branching sequence, the temptation is often to do so using a linear sequence as a basis and a guide-line. And then the task of drawing up an inventory of the real mistakes to be corrected gets neglected and forgotten. This method is dangerous, because it may lead the programmer to conceive all the possible paths in terms of the linear model and he may end up by writing in mistakes which are never made. It will easily be appreciated how disastrous it would be to force pupils to commit such mistakes simply because they have been led astray and lost their bearings.

PRE- AND POST-TESTS

These are both instruments for testing; but they differ in the testing functions they fulfil in relation to the pupils and the sequence. The final or post-test is intended to check that the pupil has in fact attained the objectives of the sequence after having studied it. If the results are not satisfactory, this may mean that the pupil has studied it badly, but it may also mean that the sequence is not a good one, or is not suited to him. The initial or pre-test is basically intended to check that the pupil possesses the knowledge required to study the sequence.

Usually tests take the form of questionnaires for pupils to answer. But they may also consist of non-verbal exercises: movements, manual tasks, simulated patterns of behaviour, etc. Let us consider them more closely.

The post-test

Here is an example. It takes the form of a page printed on both sides.

ENSAC Brazzaville

Sequence 1
Grammar

Pupil's name:
Class:

SUBJECT

QUESTIONS

Write nothing in this column

1. Think of football:
'Passing is easy; it is scoring that is difficult.'
Underline in these sentences the words which express what 'is easy' and what 'is difficult'.

2. 'The spectators cheer the best players.'
Say the same thing by writing first: 'The best players . . .'
Write your reply here:
'The best players . . . . .
. . . .

3. 'Seated in a corner, Peter was doing his homework.'
In this sentence, one word denotes who is doing something: which word?
Write the word: . . . . . .

7. 'My brother was hurt by this boy.'
Write a different sentence which says the same thing but starts with: 'This boy . . .'
Answer: 'This boy . . . . .

9. 'My friend is called Paul.'
Can you write this sentence with the *same* words but starting with the word 'Paul'?
YES NO
Underline your answer.

Description and concept of the post-test. The example given above is very simple. The test consists of a series of questions put to the pupils at the end of the programmed lesson. The responses required may take several forms: that of making a simple choice, of underlining, of writing in a word, making up a sentence, and

S.C.E.R.T., West Bengal
Library
Calcutta
25/3, B. C. Road

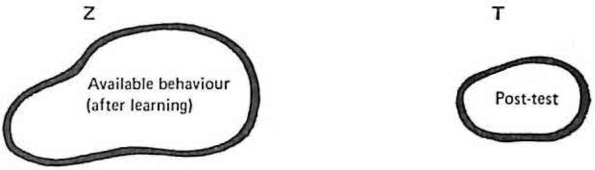


FIG. 19.

so on. In other words, the nature of the questions is not limited by the form of the responses required. Nor are there any norms for determining exactly what the content, formulation or number of the questions should be. This is particularly awkward when we are dealing with some traditional item of school instruction for which the acquisition of knowledge is tested basically by verbal means; patterns of verbal behaviour are difficult to manipulate, to provoke, and *a fortiori* to test. There is less difficulty, in principle, when the responses required are non-verbal patterns of behaviour, for example, working a machine, taking a piece of machinery to pieces, classifying such and such a group of objects, etc. But we still have no norms to establish *what* patterns of behaviour should be required if the effectiveness of the learning process is to be checked. Nor, obviously, do we know what procedures could be used automatically to define such norms.

The problem which the post-test must solve is as simple to formulate as the function it fulfils: it will check that the final behaviour Z has actually been acquired (Fig. 19). Whether this function is in fact fulfilled now comes down to a question of pure technique. Unfortunately, such techniques are in their infancy. At best they consist of advice or recommendations; at worst they consist of mere indications of what should not be done. In the absence of any norms, we will have to get along on this basis as best we can, and appeal to the inventive genius of the individual teacher. This is not to say that the experts' armoury contains no serious means of testing. But those which we have, were developed by research workers for the purposes of highly specific studies and their use cannot be generalized, because they are adapted only to the very limited fields of learning for which they were devised.

Under these circumstances, we shall proceed empirically. First, the means of testing should be conceived in operational terms. From our above examination of the definition of objectives, we know that the criteria are very inadequate. This makes the task here more complicated: testing is in the final resort no more than a well-conducted sample survey. However well we try to conduct it, it still remains a sample survey, and, as with pre-election opinion polls, certain qualities are required of it: the questions must be brief, the sample representative, the results easy to analyse.

The questions must be *brief*, since the test cannot ask for all that has been learnt to be reproduced. But even if the test uses sampling techniques, it must, like an oil prospector's core sample, provide information on the resources of a whole area. This brings out the difficulty of sampling techniques applied to education: where and how does one find the right 'core samples', bearing in mind that the area to be surveyed comprises all the final patterns of behaviour which the programmed sequence has inculcated? The problem is to obtain representative sample patterns by means of which one can check that all such patterns have been acquired. Such samples also have to inform us—and this is the second important function of the post-test—about the causes of any failures that occur, so that we can work out corrections.

The requirement that the sample should be *representative* means in this context that the question put, the sample tested, should suffice to give a full picture of what has actually been acquired.

The third requirement—that the results should be *easy to analyse* —is also quite natural. If a question gives rise to completely unexpected responses, there will be no way of telling how to correct the errors which cause those responses.

Admittedly this is, in fact, simply a question of common sense; but it is less common to find its being considered in a methodical way.

Thus we insist that the post-test should be prepared as soon as the objectives have been defined. The need for this is often not appreciated and even disregarded. Preparing the testing device before one has anything to test, looks like putting the cart before the horse. Yet the reason for this is perhaps not so much a matter of any technical requirement as of the desire to insure against certain risks.

In the first place, there is the risk of overlooking testing altogether. How many programmed courses are written today without the inclusion of any tests, either pre-tests or post-tests, so that there is no way of knowing what to use them for! It is indeed very tempting to imagine that the sequence is self-sufficient, and that the care with which it has been drawn up will overcome any obstacle which crops up in the course of study. So that is one good reason for writing the test before the sequence. Another is that any moderately experienced teacher knows the danger of testing his own pupils and then being drawn into congratulating them just because they have imitated him well. The personality and authority of the teacher interfere with the subject-matter taught and, in many cases, pupils will react to any questions put them in terms of that personality and that authority. Anyone who has done exercises or essays, or studied for examinations, knows that he is influenced by such considerations and that his replies and his treatment of a subject are dictated by his wish to adjust to the marker.

If programmed instruction is to be put to good use, an effort must be made to break this habit, as it inserts a 'third person' between the subject-matter taught and the pupils whose learning is being tested. It is common practice to ape the teacher's eccentricities, offering him as far as possible the work he is expecting, with all the tricks this process involves. This practice enables a sort of pact to be made with the teacher, assuring him of his position as a mediator between knowledge and his pupils.

This is no exaggeration. Anyone preparing a lesson and then giving it in class finds it difficult to imagine questions which, for the purpose of testing the results he has achieved, invite an external and perhaps critical point of view. Yet it is this difficult exercise we would see undertaken, since the lesson and the testing will be done in the programmer's absence. The main danger is that of putting questions which solicit, as responses, a repetition of the contents of the sequence. This checks that the sequence has been recorded to memory, but not whether its contents are truly assimilated. This is why care must be taken that the final test should not be simply a repetition of exercises already set.

But there is then the danger of going to the other extreme and setting difficult problems or putting catch questions. The final test is not a composition exercise which can be used to award a mark and rank the pupils: it does not play the part of a selective examination. A middle way must be found between these two extremes by hitting on exercises which provoke the type of response that tests the pupil's understanding.

Other functions and applications. The purpose of the test results is not solely to inform the teacher. They also tell him what mistakes have been made, and with this precise information the teacher can then put everyone back on the right path in full knowledge of the relevant circumstances. This is another function of the test which is often ignored. Yet it is a great advantage, since it gives the teacher insight and enables him to make sure, before going on

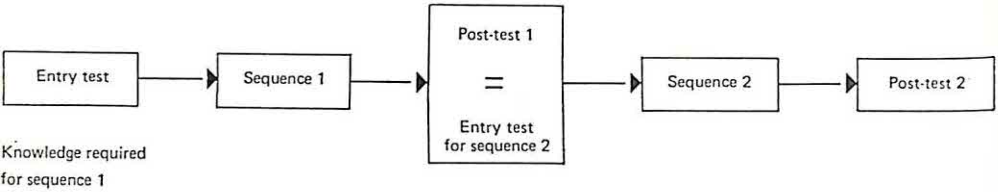


FIG. 20.

to the next lesson, that all the pupils have assimilated the previous one.

The test can have another use for the programmer: sometimes it can be used to discover whether an item it was planned to reserve for the next sequence has already been learnt. The replies obtained from such test questions can guide programmers in defining the objectives of the following sequence.

Finally, if it is planned to give a whole series of sequences, undoubtedly the post-test on the first sequence can be used to tell whether the pupil is at the required level to go on to the second. Thus the order of operations can be represented as in Figure 20.

The initial or pre-test

It would seem illogical to upset the sequence of operations by devising the pre-test *after* the post-test. But the stages in which a programmed course is worked out do not obey the same rules as the preparation of a lesson in the normal sense, mainly because we are concerned to break with those rules and the habits which underlie them. In any case, preparing the pre-test represents the third phase of group work.

Description and conception. The pre-test can have the same form, in many ways, as the final or post-test. The problem is to check that certain patterns of behaviour, verbal or non-verbal, have been mastered. We should recall that the purpose of this test is in the first place to check that the population for which it is intended has all the knowledge required to study the sequences. This function accounts for the different conception of the test: are the pupils *at* point A which is the starting point, or not as far advanced, or beyond it? The test is designed in terms of a hypothesis (or hypotheses), namely that the pupils possess the minimum required of them to embark on the sequence. This hypothesis will be borne out or not, according to the amount of knowledge (too much or too little) which the pupils possess. The results in any case will

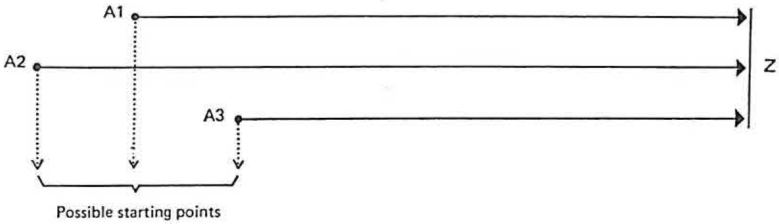


Fig. 21.

show where to place point A, which may not be where it was expected to be.

As Figure 21 shows, there are few possible alternatives.

The programmer thinks that the pupils for whom he is designing his course have knowledge A1. But it may be that they have less (case A2) or more (case A3). Whatever the programmer's starting hypothesis (A1), the pre-test which checks it must allow for the various possible alternatives, namely A2 (the required knowledge is inadequate) and A3 (not only is it adequate, but it may well encroach on the subject-matter of the lesson which is to be given). The problem, then, is not solely that of confirming or invalidating the programmer's hypothesis: in the latter case, we should be left with two possible alternatives, A2 and A3, but we should have no means of telling which corresponds to the case.

In contrast to the post-test, the pre-test is selective, since its results must enable the programmer to decide between the three hypotheses. The teacher who thinks of his own class is certain to foresee complications: his pupils are scattered over A1, A2, and A3; they are certainly not at the same level. This gives him the prospect of having to prepare three different series of lessons, depending on whether the starting line is A1, A2 or A3—not counting the possibilities of intermediate lines or the handicaps to be carried by all these 'horses' which have to cross the finishing line at the same time.

Remark. This way of presenting the pre-test is discouraging in the sense that it seems to ask the teacher to work out almost as many sequences as there are pupils; some to lead the backward pupils up to the starting line, a few more to keep the front runners occupied and patient, and a final one for those who manage to come up to the post dead on time.

This standpoint is right in the case of a single class. Understandably, the total work it involves will be disconcerting. But this is not in fact the right standpoint when we are considering the tasks of programming. When we embark on the preparation of programmed courses, we must not think in terms of a single class, but on a much larger scale, large enough that is to accommodate all pupils: those who conform to hypothesis A1 and also those who do not. Programming has no sense unless we plan for a large number of pupils.

The results of the pre-test are used, basically, to determine the initial behaviour. If we have decided that this should be A1, and the pupils do not have all the necessary knowledge, we can provide a supplement to the sequence which will fill in any gaps. This may take any desired form: a lesson of the normal type, a pre-sequence or anything else.

The pre-test is constructed just like the post-test. And this means the same precautions must be taken, because in this case too there are no codified and proved procedures. For greater certainty, sometimes a few exercises from the final test are introduced to check whether the pupils may not already have some idea of what they are to be taught.

Conclusions on tests

Although we can define the function of tests with some precision, we are nevertheless constrained by the empirical nature of the procedures for constructing them. For this reason we endeavour to limit the effects of such imperfections by taking many precautions: making up the tests before the sequence, trying to plan in behavioural terms, etc. But the best way of reducing the potential harm of the empirical approach is certainly group work or teamwork. The first attempts to work out something together will surely give rise to much discussion. These discussions are the instructor's opportunity to impress on students not only the genuine difficulties, but also the objectivity they must aim at when devising tests.

ORGANIZING THE SUBJECT-MATTER

This third stage in programming is one of the most important. It entails several quite widely differing types of technique, some of which will involve us in more detail than others in analysing the subject-matter and developing the sequence. But let us first define what we mean by organizing the subject-matter.

This comprises analysis of the subject-matter, more specifically spelling it out in terms of behaviour. It also comprises setting out and ordering the elements into which one has broken down the subject-matter; the order thus obtained forms the progression of learning. We shall now consider some of the best-known such techniques, concentrating on the most satisfactory way of presenting them to teachers.

The Davies matrix method

This is the further development of another technique invented by Homme and Glaser and known by the label RULEG. This word is made up of the abbreviation RU(L) for 'rule' and EG in the sense of 'for example'. Briefly, the object of this technique is to provide an analysis of the contents of the sequence, an analysis, that is, of what separates initial and terminal behaviour. In behavioural terms, this must be spelt out in the form of rules (symbolized by the letters 'ru') and examples (symbolized by the letters 'eg').

A rule is an idea, a general concept, an abstraction, a principle, etc., which, in operational terms, consists of precisely circumscribed patterns of behaviour.

An example is the illustration of a rule, a particular case of it, one of its applications, and so on.

We shall be content with this short statement, since the original idea of the inventors of RULEG is taken up within the framework of the Davies technique, which we shall discuss at greater length. This technique has the advantage of being based on a theory, or at least on certain principles relating to the acquisition of concepts.

Principles governing the acquisition of concepts. A concept is an activity of varying complexity, the manifestations of which can be observed. Concept-forming requires the exercise of activity directed towards two complementary tasks: generalization and discrimination. Here is a provisional definition of generalization:

Concept-forming requires generalization within classes. Intra-class generalization is easily achieved through a series consisting of an infinite number of incomplete examples [8]. In other words, generalization means the tendency to produce one response to a given set of stimuli.

Inter-class discrimination is achieved by including negative examples (eg), that is, examples which are not applications of the rule under consideration [9].

Discrimination expresses the tendency to give different responses to different stimuli [10].

Thus the first task is to enumerate the concepts which are to be acquired by means of generalization and discrimination.

The unordered listing of concepts. The group will be asked to define these concepts, regardless of the order in which they lead on to each other. For the moment the task is only to draw up a comprehensive list. Therefore this task is separate from that of establishing an order within the set of items discovered. Even if this distinction is not made quite so explicitly in Davies' original account, it has several interesting advantages for the instructor. We have seen how the very way in which a subject is taught can influence a teacher when he discusses that subject with his colleagues. Thus his grasp of the concepts is often falsified by the order in which they are taught. By leaving order aside provisionally, we make discussion of the subject itself easier, even if the merging of ideas and clash of opinions may give an outward impression of incoherence.

It is probably at this point that the major difficulties will arise. The mental discipline required for the explicit redefinition of the subject-matter may well call for unwonted skill, which largely explains why this stage of programming is the one at which the content of what is to be taught is challenged. It is no longer possible to say 'a proposition consists of subject, verb, object. . . . First we shall talk about the subject, then about the verb, etc.' Our remarks here are similar to those of P. Greco when he brings out the diversity of interpretations to which some expressions concerning the definition of objectives lead [11].

. . . *Expressions of the type 'to have the concept of area', 'to understand group structure', etc., may, outside the experimental context in which the psychologist has assigned them precise operational definitions, be interpreted in a multitude of different ways. The eighteen-month-old baby who reaches some object a little way away from him by using a new combination of various movements, and then returns to his point of departure by a different route, 'possesses' in some sense a 'group of movements'. No doubt he has no representation of it in image form, still less in algebraic form, but it is not going too far to say that he 'understands' this group, since he invents appropriate and non-habitual routes to solve new problems; a 'practical' understanding, admittedly, but an understanding and not a mere acquired habit or locomotive pattern passively undergone* [12].

'Subject' is only a word; the group will have to determine what it means precisely and what it will have to mean to the pupil. Here only the habit of group work can show the magnitude of the problems which every discipline raises, and such problems vary from one discipline to another. But it is common knowledge that such problems are specific to each discipline, and that no expert can take an over-all view. The programmed learning specialist is incapable of solving them; he is only manipulating techniques, which can themselves do only what they are made to do. He can never take the place of the expert in a subject and decide for him the questions which the expert encounters.

The problem is to draw up an unordered list of the ru's covering the whole area of the subject chosen. Here is an example, which is in no way meant as a model, relating to a sequence intended to teach certain definitions as an introduction to the concept of 'set' in mathematics.

1. Mention of the idea of set when presenting collections of objects. Association of the idea of set with collections of identifiable objects.
2. A collection of specific objects constitutes a set.
3. The symbols for set and item. They are conventional.
4. An object and a particular part of that object are considered as two distinct objects.
5. For any set under consideration, it can be determined whether a given object is a member of the set.
6. A diagrammatic presentation of sets and items.
7. Notations; reading the formula defining a set by its extension.
8. Distinction between the singleton set and its member.
9. For any object under consideration, it can be determined whether or not it is a member of a given set.
10. Definition of the relation of membership.
11. Definition of the relation of non-membership: the symbol, reading the formula.
12. A set can be defined by the full enumeration of its members: this is called an 'extensional' definition.
13. A one-member set is called a singleton.

Each of the rules listed has been given a number, but it does not indicate an order; for the moment it is simply a means of identification. It is not until the subject is being discussed by the group that it will decide whether a given concept is part of the subject, whether it is a rule, whether it repeats another rule, whether it does not rather constitute an example or a specific case and so on. As the discussion progresses, note will thus be taken of what is entitled to be called a rule, regardless of the relations between rules. In practice, it can be observed that each participant has his own idea of the rules and their sequence. Our reason for refusing to establish a sequential order at this stage is in fact that we do not wish to settle at the outset, without criteria, in favour of one participant's opinion rather than another's. The 'disorder' of the list in a sense reflects the many different orderings which may have clashed with each other during the discussion.

We need hardly point out how important a place, once again, this procedure gives to intuition and empiricism.

Many will ask on what criteria we base the assertion that something is a ru and not an eg or on what grounds we contend that such a notion does not go outside the subject, or is necessary to the study of that subject, etc. In all this, programmed instruction can rightly be accused of empiricism. Although the criticism is justified, the conclusions drawn from it are sometimes less justified. Admittedly we have no real criteria for deriving, distinguishing and formulating rules; however, it is also true that the difficulties and disagreements encountered in spelling out the subject-matter affect only the experts in the subject which is being treated. In other words, we acknowledge the empiricism of the procedures, but this should not thereafter become an excuse for laying at the door of empiricism any trouble which arises with the subject-matter! It is only fair to admit also that the use of this type of technique may serve to reveal the existence of such trouble. If so, it is not necessarily a subject of complaint if unsuspected difficulties are discovered. Here is one testimony:

> . . . *it is held that the self-deluding confidence of many university professors —their belief that academic skills or critical thinking can be conveyed by intuitive methods—has been shaken by the successful application of some of the latest techniques, particularly in the field of educational television and programmed instruction* [13].

But the teacher-educator would be wrong to expect the practice of such techniques automatically to produce these fringe benefits. He will have to pursue them himself, through his own experience with the conviction that, for the time being at least, these 'fringe' benefits are in fact the most important.

Setting up and using the Davies matrix. We now have the task of establishing the order in which the rules will be presented in the sequence. Only later shall we be concerned with the eg's—the examples.

Here briefly is how the desired order is arrived at.

First a grid, or matrix, is drawn up with equal numbers of rows and columns, the number of either being equal to the number of rules in the unordered list.

The numbers identifying the rules are entered diagonally, as in Figure 22 (a). The grid will be used to draw a synoptic table of

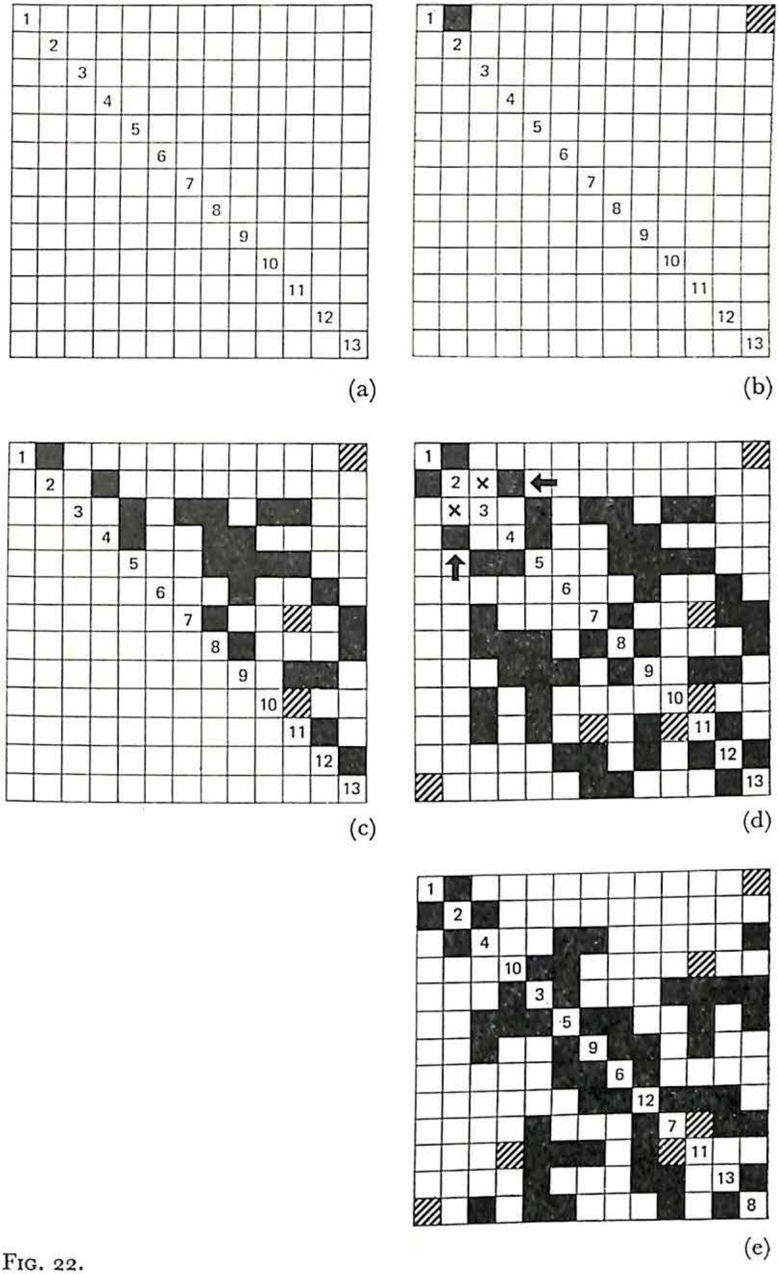

1 2 3 4 5 6 7 8 9 10 11 12 13
(a)
1 2 3 4 5 6 7 8 9 10 11 12 13
(b)
1 2 3 4 5 6 7 8 9 10 11 12 13
(c)
1 2 × × 3 4 5 6 7 8 9 10 11 12 13
(d)
1 2 4 10 3 5 9 6 12 7 11 13 8
(e)

FIG. 22.

the relations between the rules; association and discrimination are the criteria by which these are defined. The operation is done in two phases and, in this case, in slightly more than three movements.

Let us consider the row containing ru 1. Let us ask ourselves whether, between this rule and the others, there are any links as defined by the criteria above. For example: Between ru 1 and ru 2? Yes: association, and induction, so we blacken the square in row 1 where it intersects with column 2 (Fig. 22 (b)). Between ru 1 and ru 3? No connexion: we leave row 1 column 3 blank. Between ru 1 and ru 4? None there either: we leave row 1 column 4 blank. And so on with all binary elements beginning with 1: 1-5, 1-6, right down to 1-13. When there is a relation of association, this is noted by filling in a black square at the intersection of the row and the column. If the relation is one of discrimination, it is represented at the intersection by a diagonally shaded square. Naturally this mode of representation is purely conventional.

When we have considered all the squares in row 1, we move on to row 2. We then consider the following relationships: 2-3, 2-4, 2-5 . . . 2-13. Then we look at row 3: intersections 3-4, 3-5 . . . etc. And so on until the last line which needs to be looked at: the twelfth. The result may, for example, be as shown in Figure 22 (c). All the squares to the right of the diagonal have been examined for association and/or discrimination. Whether the squares are blacked in, left blank or cross-shaded, the task is tiring and demands concentration. The choice of any of the three presupposes some hard thinking, and the number of squares for which this effort has to be repeated makes it difficult to keep up. Yet the effort must be made.

Over the whole range of relationships represented in this way, there are many different kinds, and there may well have been some hesitation before we blacked in a square or left it blank. Let us now, therefore, write out in the case of each the reasons for the choice made, even if these only take the form of jottings (for example, 1-2, reason: . . . ; 1-3, reason: . . . , etc.). These notes will come in useful during the second phase of application of the matrix.

But how do we fill in the first square? Several questions could be asked: is there between ru 1 and ru 2 a relationship of discrimination or association? None of discrimination; one of association, then?—Yes, more likely. Is it induction?—Yes, perhaps, but do you mean that the idea of set is introduced by the idea of collection? The reply may be yes or no, depending on how you think we approach the concept of set. If yes, the square in question is blacked in, and then the others.

The second phase of the operation is intended to check the results of the first, and the whole of the part below the diagonal is used for this purpose. The previous process is repeated in reverse order, but according to the same plan. First we consider the row in which 13 is entered and for each square we shall ask the question which we put to ourselves on the first occasion, but the other way round: 13-12, 13-11, 13-10, . . . 13-1. Then we move on to the next line above: 12-11, 12-10, 12-9 . . ., and so on until the last: 2-1. Once again we recommend that the reasons for the choice made should be indicated in each case, on a page where all the binary elements are arranged in columns. Once again, the system of black for association, shading for discrimination and blank for unrelatedness should be applied.

When all this has been carefully considered and carried out, the two sides of the diagonal should obviously be symmetrical (Fig. 22 (d)); all that has happened is that we have repeated below the diagonal what we did above it. If it really is repeated, this will be seen from the symmetry.

But we may get an asymmetrical arrangement. Then we have to reconsider the nature of the disputed links, and decide on which side or sides the grid is to be corrected—'grid' because, strictly speaking, it is not a true matrix, the latter term being used only by analogy. It is at this point that a summary of the decisions made for each of the squares can prove useful, forestalling any later re-opening of the discussion.

After the ordeal of working out the grid, it would be most inappropriate to risk the group's returning to square one. It is therefore better to be methodical from the outset, even if unsuspected short cuts can later be made. During the first attempt, this is an indispensable precaution if discouragement is to be avoided.

We now have a highly condensed picture of the foregoing operations, since the grid shows simultaneously the rules identified by number, the relationships between them, and the nature of those relationships. In addition, there are the summary notes relating to each. We have collected all the materials and are ready to establish the order in which we shall present them. So we now want to know how to handle them to deduce the desired order. Before examining the procedures, let us look at the principles.

All the connexions between the key concepts—for that is what the rules are—have been identified and distinguished according to whether they are associative or discriminatory. We should not forget that concepts are learnt by means of these two types of operations. This being so, arranging the rules will have the effect of organizing the relationships, and more especially of linking together the operations of learning. Thus to order the rules is also to define an order of learning. We shall return to this idea.

All relationships are indicated on the grid, but the scattered distribution of the black or shaded squares shows that in many instances the rules are not linked together. Were we to rearrange the rules on the diagonal, however, the squares too would be rearranged. The rules will be linked together, one after another, when the two sets of squares on either side of the diagonal have been filled in black.

If, for example, we put 4 in the place of 3, the squares indicated by the arrows in Figure 22 (d) will be transferred to next to 2 (to the squares marked with crosses). We can put the 3 after the 4, then the 10, etc. Figure 22 (e) provides one instance of a rearrangement of the rules which brings the black squares into a more dense grouping around the diagonal. Undoubtedly, other orderings could be found satisfying this requirement, and the one we suggest in this figure is not necessarily better than any others, it is only there as an example. But let us imagine that no better ordering is found, and that after several tries this is the arrangement which turns out to be the most satisfactory. We shall now rewrite the list of rules in the order in which numbers identifying them occur on the diagonal. Next we shall give each of them a new number, but this time it will be a serial number. The ordering we arrive at in this way is the order of learning. (See table opposite.)

The *logical order and the order of learning*[1] are identified. This means that we propose to teach the concepts in exactly the order of their interconnexion on the level of contents. Whenever the point is put in this way, there is a general outcry; in the resulting confusion, the teachers condemn this attitude, which they say ignores pupils' 'psychology' and the need to adjust to it. For them it is just as if we wished to teach pupils mathematical concepts without taking the pupils themselves into account in the least. The concepts have a logical order in terms of the logic of mathematics itself—this they admit—but it is far from certain that pupils should be taught the concepts in the sequence in which they occur in that logic.

Put in these or similar terms, the comment is a general one and shows profound concern which is usually expressed as a fear of the consequences: the confusion, it is claimed, itself opens the

---

[1] By the latter expression we mean the order in which the concepts are expounded or taught

Ordered list of rules

Number identifying the rule	Serial number	Formulation
1	1	Mention of the idea of set when presenting collections of objects. Association of the idea of set with collection of identifiable objects.
2	2	A collection of specific objects constitutes a set.
4	3	An object and a particular part of that object are considered as two distinct objects.
10	4	Definition of the relation of membership.
3	5	The symbols for set and item. They are conventional.
5	6	For any set under consideration, it can be determined whether a given object is a member of the set.
9	7	For any object under consideration it can be determined whether or not it is a member of a given set.
6	8	A diagrammatic presentation of sets and items.
12	9	A set can be defined by the full enumeration of its members: this is called an 'extensional' definition.
7	10	Notations; reading the formula defining a set by its extension.
11	11	Definition of the relation of non-membership: the symbol, reading the formula.
13	12	A one-member set is called a singleton.
8	13	Distinction between the singleton set and its member.

door to surreptitious 'conditioning'. And this argument is presented as a decisive criticism of the whole Skinnerian approach. But this criticism is baseless. For if there is such a thing as a concept, laboratory studies would tend to indicate that its mode of existence, its reality, must be grasped in the very terms used in acquiring or learning it. To put it more strongly, having a concept is no more and no less than the set of items of know-how which one has learnt. The same is true of the notions which are part of the extensions of this concept, and which are arranged according to a certain logic. The more enlightened the learning process, the more clearly this logic is reflected, and this is beneficial for pupils since it spares them many meanderings. In this light, the idea of a logical order distinct from the order of learning seems out of place. It is a symptom of the survival of an intuitionist psychology which teachers use as an excuse to put off the indispensable rethinking of their ideas on the contents of their teaching. Before hitting one's head against a brick wall, it is preferable to know whether it will stand the shock.

For once again the criticism misses its target. Certainly, when people speak of an order of learning—or of teaching—distinct from the logical order linking the concepts used in a given subject, they are talking out of genuine experience. But often that experience is not based on certain knowledge of the inherent logical order (what a French student of Descartes has called '*l'ordre des raisons*') instead the difference postulated between the two orders is a sort of refuge from one's uncertainties concerning the logical order!

The fact remains that application of the Davies grid shows the many different paths which in practice may be taken: there are several alternative ways of linking together the rules, and as many different alternative sequences of learning. Here we should stress that this is the first time that we have come across anything properly resembling a technique in programming work. This is why it seems more in the nature of general instructions than one might have wished!

Establishing the flow-chart. The order of progression is represented by the rules in the form of a list. What we now have to do is to elaborate in greater detail the passage from one rule to the next. For this we have two guide-lines: we must use association and discrimination. We will endeavour to keep to these guide-lines in the contents of the examples and the use we make of them. The easiest way of achieving this is to distinguish between several different categories of ru and eg [14], for which the symbols are the following:

ru: complete rule
r͠u: incomplete rule
r͞u: negative rule

eg: complete example
e͠g: incomplete example
e͞g: negative example.

Leplat has described their use thus:

A rule is a notion to which access is gained through a series of approaches which may be simulated by situations presented in the form of examples. At first these examples (eg) will be explicit and will bring out all the characteristics of the notion. Then more examples are presented in which the notion is present, but with gradually fewer characteristics (e͠g); the learner is asked to complete the latter. In the course of the lesson or at the end, cases are presented which do not entail the notion, to check that a distinction is being made between that notion and others (eg). The same general process applies to the rules (ru, ru). By using all these types *alternately or simultaneously, a process can be defined in which generalization and discrimination are at work* [15].

Let us illustrate this not with an extract from a sequence, but by a child's game: *pigeon vole* (the pigeon flies). It is played by two children: one leads by giving the names of an object or living being, the other must answer '*vole*' ('flies') when this is in fact something that flies. We can imagine how the notion of flight could be refined by diversifying it into categories: first birds, then insects, then contraptions. For each category there can gradually be brought out certain prerequisites for flight; for instance, with birds, the size of the wings. An illustration of generalization, from Skinner, was given in connexion with learning the spelling of the word 'manufacture': the examples are increasingly incomplete until the student is asked to fill in the whole word. The element of discrimination is meant to consist in checking that the pupil does not confuse the word in question with others of similar spelling.

Thus, in the case of each rule, it must be decided what examples should be used, how many, what should be their content, in what order they should be introduced, what components or features of the rule one wishes to stress (cf. the extract from the linear sequence on the grammar of sets, p. 53), etc. In the case of rule 1, for instance, the sequence of items is as follows:

$$\text{eg-}\widetilde{\text{eg}}\text{-}\widetilde{\text{eg}}\text{-}\widetilde{\text{eg}}\text{-}\overline{\text{eg}}\text{-eg} + \widetilde{\text{ru}}\text{-}\widetilde{\text{ru}}\text{-ru-}\overline{\text{eg}} + \overline{\text{ru}}\text{-ru}$$

The same process is applied to each of the other rules. As a safeguard, reminders and recaps are included, or alternatively the learner is made to give them himself, in order to avoid breaks in the development and also to avoid leaving the pupils with the feeling that continuity is lacking.

The whole of this work is summarized in a synoptic table called the 'flow-chart', which gives a picture of the process defined by means of the symbols ru and eg. Here is an example (Fig. 23) on an entirely different subject.

This chart is rather pointless if it does not refer to other records which have been duly kept; it is meaningless unless we know what the eg's and ru's in the different squares refer to. This is why it is necessary, in the case of each of the analysed rules, not only to draw up a list of examples or incomplete rules which describe the learning process selected, but also to keep such lists; the diagram is only a summary, a card-file of symbols which gives an over-all view.

The diagram is constructed in a very simple way: each row is

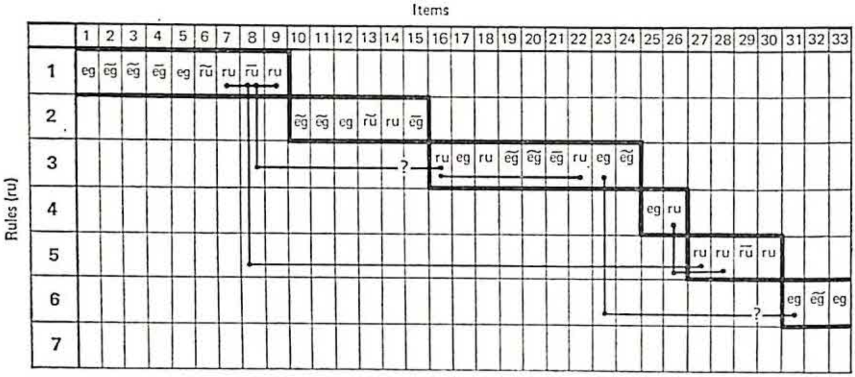


FIG. 23.

reserved for one ru, identified at the left one after another; the columns are used to indicate what learning each rule comprises. Thus, in the case of rule 1, there are nine stages: eg, e͠g, e͠g, e͞g, eg, r͠u, ru, r͞u, ru. The order of these stages corresponds to that of the items agreed as requisite for study of this rule, and refers to the list describing it; the numbers of the columns are in fact designed to show this order. When we move on to rule 2 we start with the tenth stage, obviously (column 10), but we change row (row 2).

But the diagram can have other purposes in addition to that of presenting visually the over-all development and flow of the sequence. We stress this not because its other functions are of great importance, but because the possibilities of the diagram are often neglected.

First, it is possible to note reminders, and when these will be introduced, on the diagram, they have been drawn in as linking lines. The r͞u (column 8, row 1) is recalled in the form ru (column 16, row 3). But this in itself would be of little interest. It is possible to be more ambitious and make stage 16, not a reminder, but instead a check on whether such a reminder should be included or not.

Stage 16 then becomes a sort of test intended to verify a hypothesis: the hypothesis that stage 8 has been memorized. According to the findings, we shall judge whether or not to include a reminder. Thus a certain number of hypotheses can be formulated, and perhaps there would be no harm in entering them on the chart (by means of a question-mark, for instance).

Secondly, the diagram can be used to give an approximate indication of what the frames of the sequence contain, and conse-

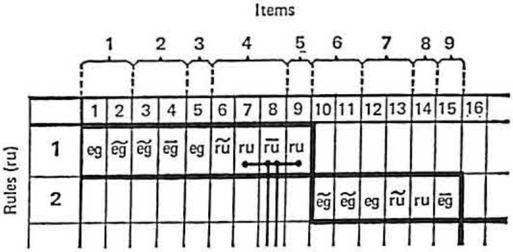


FIG. 24.

quently the 'dimensions' of the sequence. By consulting the lists which set out the processes for studying each rule, we shall be able to decide what each step or frame will comprise. In the case of rule 1, let us imagine that we decide that it will contain the introduction of a complete example (eg: stage 1) and another, similar example to be completed (eg̃: stage 2). What we are here being asked to plan is less the number of frames than the scheduling of reinforcing contingencies. This will be noted on the diagram, in the form of a blueprint: stage 1 and 2 make up the content of frame No. 1 in a linear sequence. The content of succeeding frames will be determined in the same way (Fig. 24).

The same suggestion made above in the case of reminders can be followed here: plans relating to the content of frames can be conceived somewhat like hypotheses. We postulate that the two eg's (stages 2 and 3) are adequate to allow the pupil to carry out the discrimination which is required at 4. The question put in frame No. 2 will thus have the function of checking the validity of this hypothesis.

With these functions the chart will serve as a guide during the next stage, which is that of writing the programme, and also as a check-sheet for interpreting the findings when the sequence is first run. It will then help to show what corrections are necessary.

We have seen that by this means it is possible to define the content of items or frames in a linear programme. Even if we want to write a branching sequence, the information in the diagram is still useful. Davies suggests that the content of a key item or frame should be defined by the stages which the learning of a rule entails (see Fig. 25).

But in thus planning ahead the sequence in which items or frames will come, we may lose sight of the mistakes which we wish to test and identify during the learning process in order to correct them. This is our opportunity to take into account any information or results of investigation by means of which mistakes were

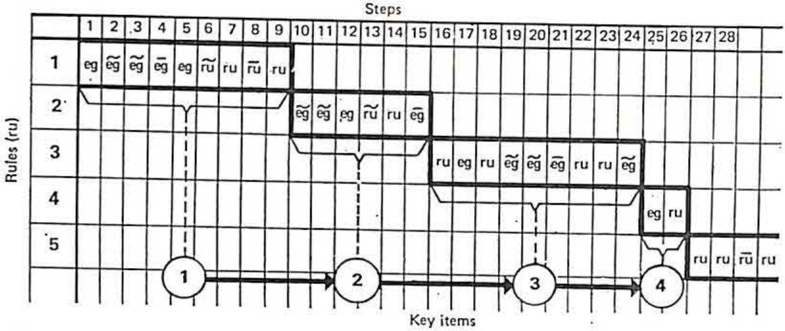


FIG. 25.

traced. In this way such mistakes may even point to other possibilities of using generalization and discrimination for our purposes.

Because if there is a mistake, it must be because the pupil is doing either or both of these operations badly. This being so, the processes for studying the various rules must reveal where he is going wrong and show how to put him right. Consequently, the flow-chart may very well differ from one designed for a linear programme. Since mistakes must be detected and corrected, we see that decisive importance attaches to the chart's function of formulating and exemplifying hypotheses, because the testing of such hypotheses becomes in itself the means of deciding the next step. Thus, unexpectedly perhaps, we recommend that programmers should not await the completion of the diagram before deciding the type of programme to be adopted. This choice is a preliminary one, since the use made of the diagram, its form and its content all differ according to the choice made.

Remarks. The combined use of rules and examples in the definition of the learning process sometimes gives rise to confusion over terminology. The method of giving many examples *before* formulating the concept they illustrate is termed 'inductive', by contrast with the 'deductive' method, by which first the rule or concept is presented, followed by the examples. The former is also called a 'discovery' method, while the supposed effect of the second is to condition. Neither use of the terms has any bearing on the learning of knowledge which in fact is either presented systematically in a formalized manner or in accordance with the rules of the experimental method. If we achieve anything resembling a strict scientific approach with these techniques, this is not attributable to them alone; and if we do not, it is unfair to lay the entire blame at their door.

Once the flow-chart has been completed, we are very near the final planning of the sequence. Now it need only be put into practice and it may be wondered why this was not done previously, when we already had the necessary material. The reason is our desire to keep separate the various operations by which the sequence is constructed and, in the same spirit, our concern to put off the moment of writing and editing it. Writing the programme which may appear to be the easiest part, in fact presents the thorniest problems if we are not adequately prepared against them. But the same is true of other techniques, for instance, mathematics, semantic analysis or behavioural analysis, the last of which we shall now examine.

Behavioural analysis

This is one of the easiest techniques for organizing the subject-matter, even if it is not the most fully perfected. Its origins are obscure, but it can be understood and applied once parallels are provided between it and other techniques. As with the techniques described above, behavioural analysis entails a theory of concept-forming which is also based on the twofold activities of generalization and discrimination.

The principles were laid down by Francis Mechner, an American psychologist who studied, in particular, the conditions for memorizing, forgetting and retaining. He noted that forgetting was not simply a loss of knowledge, but an inevitable process brought about by the mixing of new and old knowledge, some parts of which are handled more frequently than others. Once forgetting is recognized as inevitable, it must necessarily be allowed for in a learning process, where it is bound to occur. Reviewing what has been learnt is not only a safeguard, but an essential aspect of the process.

This consideration gave rise to the idea of judiciously blending the introduction of new knowledge and the recalling of old, without however losing sight of the difference between the two. Here, in principle, is how we would go about teaching a subject:

Select between 5 and 20 key words 'defining' the subject. The key words, which will serve as chapter headings, are written out on red cards and then put in order.

We then take each red card and define the word or words on it in terms of other words, which in their turn we write out on yellow cards and put in order.

We then take the yellow cards one by one and analyse the key word or words on them into other key words; the results are written on green cards which are then put in order.

The operation is repeated on the green cards, the results being noted on blue cards.

The blue cards should now contain the 'atoms' of the knowledge to be communicated. These atoms should be so elementary that a new word can be introduced approximately every five or ten items in the programme. The cards thus ordered correspond to the flow-chart, and illustrate how juxtaposition and contrast can favour the acquisition of new knowledge without confusing it with the old, and therefore without forgetting. The cards represented in Figure 26 have been numbered and put in order. The diagram shows the fact that the contents of a green card can be learnt only after those of a differently coloured card have been acquired; in the absence of any chance to differentiate, confusion would occur and lead to forgetting. To avoid this, we shall take the cards in the following order: 1, 2, 3, 4, 5, 6 (blue), 7 (green), 8, 9, 10 (blue), 11 (green), etc. The whole looks rather like a tree; to reach the trunk, first all the leaves on one twig must be explored, then all the twigs until the small branch is reached, and so on until the trunk is attained. There is nothing complicated about this system, which is presented primarily to recall the studies in connexion with which Mechner suggested this technique.

In order to convey the advantages of behavioural analysis, it is useful to make reference to another similar technique, namely, PERT or PERT COST planning [17]. PERT procedures are used to establish, in the case of a firm for example, the optimum planning of its production activities. This requires as a first step, a minute analysis of all the processes, and of their duration. Secondly, they are put in the optimum order.

The aim is to plan the optimum starting time for all activities, so that each activity is ready to start when the preceding one is completed, neither earlier nor later. All the processes in this system are based on one requirement: to obtain a finished product with minimum waste of time. Once the aim is set, then the procedure is to work back from this point of arrival, one stage at a time from operation to operation as systematically as possible, while trying to prevent delays and bottlenecks from arising. Once the analysis of the elementary tasks is complete, the whole purpose of the PERT technique is to apply this ordering to the actual production process and thus optimize the course of operations. Here there is an obvious parallel with the task of drawing up

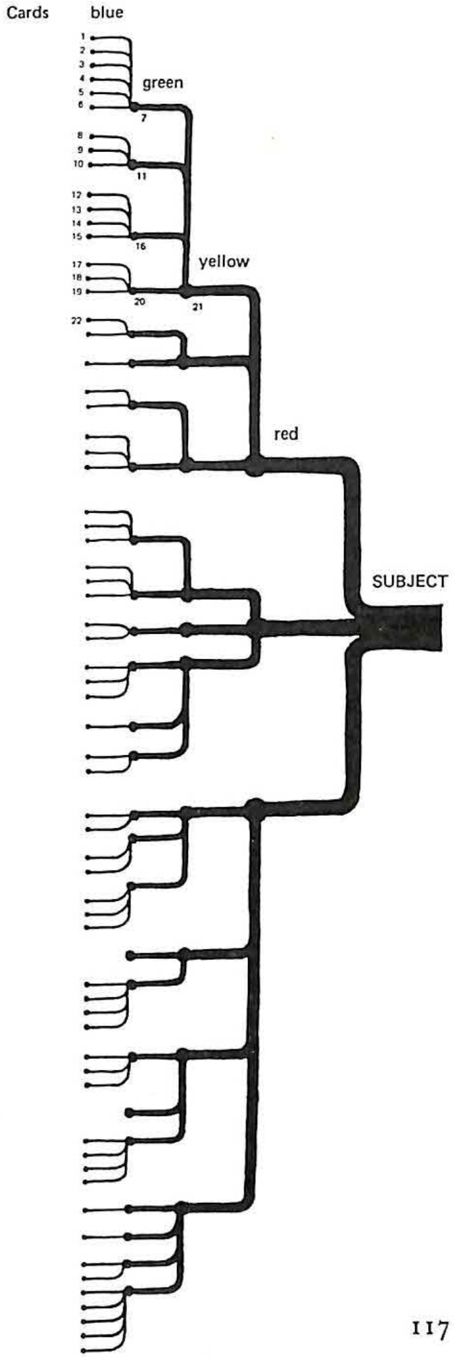

Cards
blue
green
yellow
red
SUBJECT

FIG. 26.

a programmed learning sequence. The analogy becomes even more striking when we consider how behavioural analysis organizes the subject-matter of instruction in a logical order.

Description. The initial definition of aims is in behavioural terms, but it will now be expressed in a small number of key words, and as concisely as possible. Each of these key words will be defined in its turn in the same way in a short formula, the key words of which will form the subject of a new definition, and so forth until the definitions given are felt to correspond to patterns of behaviour acquired by the pupils. Thus the principle followed in organizing subject-matter is similar to Mechner's. The practical techniques used were developed by Mr. Le Xuan, an expert on programmed instruction. They involve a number of stages.

First, the final or terminal behaviour is defined (the aims of the sequence). Then the content of the items is analysed by the following method: take a sheet of paper; divide it into two columns; at the top of the left-hand column write the number 1, and after this the formula defining the aims; in the right-hand column opposite, write the words denoting important concepts, separating them and numbering them from 2 onwards.

1	Formula defining the aims of the sequence	**2** **3** **4**	Key-word A: definition Key-word B: definition Key-word C: definition
2	Definition of A	5 6 7 8	Definition of T1 Definition of T2 Definition of T3 Spelling of the word W
3	Definition of B	9 10	F1 F2
4	Definition of C	11 12	*a* *b*

Thus words A, B, and C—or the concepts or patterns of behaviour they represent—fully describe the aim expressed in 1; in the terms used by practitioners of this technique, they 'analyse' the content of 1. In other words: 'The acquisition of A, B and C is necessary in order to achieve 1.' If this is so, we have determined the patterns of behaviour indispensable for shaping the final pattern. Before continuing, a line is drawn across the width of the page.

Next the definition of A is entered in the left-hand column. It is expressed in the same way as the aims, i.e. a few, precise terms. We then ask ourselves: 'What patterns of behaviour are necessary in order for A to be acquired?' Let us assume that it is necessary to be able to carry out three operations, T1, T2, and T3, and to know the spelling of a word W expressing an item of knowledge. The whole of this—i.e. the definition of T1, T2 and T3, together with W—is entered in the right-hand column opposite the 2 which was repeated in the left-hand column. Each definition is now numbered, starting with 5 (which follows on from the number 4 entered above it).

Concepts 5, 6, 7 and 8 describe the behaviour defined by A. In other words, in order to learn A, these concepts must first be acquired. Then 3 is transferred to the left-hand column, and we continue the description of the previous knowledge required for this to be learnt. Suppose that a knowledge of two formulae F1 and F2 is necessary (electrical or chemical formulae, for instance).

The process may seem complicated but in fact, all that is required is that the numbers in either column should be successive, and that the left-hand column start with 1 and the right-hand column with 2. When do we stop? When we see that none of the definitions being given requires any learning, because all are already acquired; in this case we simply write 'Acquired' in the right-hand columns. The process of analysis is finished when the highest numbered definition on the right has been transferred to the left, and 'Acquired' has been written in opposite. Here is a diagram setting out the result. (See also Fig. 26 above.)

1	Formula defining the aims of the sequence	2	Key-word A: definition
		3	Key-word B: definition
		4	Key-word C: definition
2	Definition of A	5	Definition of T1
		6	Definition of T2
		7	Definition of T3
		8	Spelling of the word W
3	Definition of B	9	Knowledge of formula F1
		10	Knowledge of formula F2
4	Definition of C	11	Ability to draw diagram S1
		12	Ability to use a compass
5	Definition of T1	13	Measuring a length in cm
		14	Knowledge of units in which area is measured
6	Definition of T2		Acquired

7	Definition of T3	15 16	Doing a binary addition Doing a binary multiplication
8	Spelling of word W		Acquired
9	Knowledge of formula F1	17 18	Knowledge of formula F3 Knowledge of formula F4
10	Knowledge of formula F2	19	Knowledge of units in which volume is measured
11	Ability to draw diagram S1		Acquired
12	Ability to use a compass		Acquired
13	Measuring a length in cm		Acquired
14	Knowledge of units in which area is measured		Acquired
15	Doing a binary addition	20 21	Knowledge of the binary system Binary addition procedures
16	Doing a binary multiplication	22 23	Knowledge of the binary system Binary multiplication: procedures
17	Knowledge of formula F3		Acquired
18	Knowledge of formula F4		Acquired
19	Knowledge of units in which volume is measured		Acquired
20	Knowledge of the binary system		Acquired
21	Procedures of binary addition	24	Reminders
22	Knowledge of the binary system		Acquired
23	Procedures of binary multiplication	25	Reminders
24	Reminders to be carried out (+)	26	Reminders carried out on +
25	Reminders to be done (×)	27	Reminders carried out on ×
26	Reminders on +		Acquired
27	Reminders on ×		ACQUIRED END

How do we proceed in practice? First of all, some division of labour is suggested for the team-work between, on the one hand, the experts in the subject taught, and on the other the experts in analysis. The latter are the technicians who help the former to spell out their aims, determine what is 'acquired' and express in operational terms what is to be learnt.

The analyst is in some sense an interviewer who knows how the answers should be calibrated, or the moulds into which they must be cast, but not what the answers are. The subject expert is there to say what he wishes to teach, and whether he agrees with the formulations proposed by the analyst to interpret those wishes. The analyst's function is therefore essential, since his job is that of the Socratic midwife. Finally, he will use the material to construct the sequence—to define its course and the schedule of reinforcements cues and prompts.

Comment. In the actual conditions of teaching, such a division of labour would seem undesirable. The idea of divorcing the question of the content of teaching from that of the methods best suited for teaching it, seems misguided in the absence of any reliable guide to the relationship and differences between them. To put it bluntly, this means that the 'programmed instruction expert' is as shadowy a figure as the 'educational psychologist': he knows as little as the latter does about his own field of activity and working methods.

The technician in programmed instruction, whether he calls himself 'analyst' or 'programmer', is in no way an expert except in terms of, and in relation to, a subject which he has mastered. Outside that subject he is not competent to pronounce on methods or types of sequence; the knowledge of the learning processes which psychology affords, and the knowledge of programming techniques are not sufficient for him to be able to decide how the subject-matter should be presented. There are several reasons for this opinion. First, the lack of strict principles for the application of psychological data to teaching, and the empirical nature of programming techniques which has been continually stressed. Finally, in our opinion, it is very risky to delegate to the technician decisions concerning problems for which he has not the required skills. The psychologist, the sociologist, the linguist, etc., may criticize the teaching methods of a given discipline by appealing to the facts established by their sciences. The same is true of the technician in the field of audio-visual aids or programmed instruction, although here his criticism will be based not on scientific findings, but on acquired experience. But none of them is in a position to give anything more than advice. In the end, knowledge of the subject prevails, and is used to get the fullest benefit from such advice. Educational technology, to a greater extent than the sciences to which would-be scientific pedagogical theory turns, depends on the subject to be taught and the aims assigned to that subject. It is, therefore, suggested that readers dismiss from their minds the picture of a programmed instruction expert who might tell geographers, mathematicians, chemists, etc., how and what to teach!

We recommend that the application of this technique, as of other techniques, should be left to its users, the teachers, who must, in fact, decide the best use that can be made of it. The technician should limit himself to describing the technique and warning teachers as to what it cannot be expected to do. When the problem is to spell out the content of a concept succinctly, the main difficulty is to define this concept for the pupil who will have to learn it, i.e. to state on each occasion what must already be known in order to understand the concept. For each of the concepts transferred from the right-hand column to the left-hand column there must be this sort of reflection. But the description of the 'required knowledge' which is summarized by the right-hand column is not only conceptual; again generalization and discrimination must be applied, as in the case of the Davies technique. Therefore the description may be very detailed, comprising examples (illustrations, diagrams, etc.), negative examples, teaching aids (slides, tools, etc.) and so forth. We recommend that an extra effort should be made over and above what is required for such analysis: an effort to 'describe' each of the concepts entered on the left by the subconcepts which its learning entails. In this way it will be possible to avoid breaks in continuity in the course of the sequence.

As in the preceding case, once the components of the sequence have been analysed, it is necessary to decide the order in which they should be presented and taught.

CONSTRUCTING THE FLOW-CHART OR MECHNER 'TREE'

This is a synoptic presentation of the data which have been subjected to 'analysis' and set out in two-column tables. Here we have the 'tree' which summarizes the analysis of Figure 26—see Figure 27 below. Concept 1 (aim) is represented at the top by its serial number. Beneath it, 2, 3 and 4 have been connected to it, according to the description in Figure 26. And the same has been done for all the concepts, omitting only the entry 'acquired' beneath those for which there is no need for instruction.

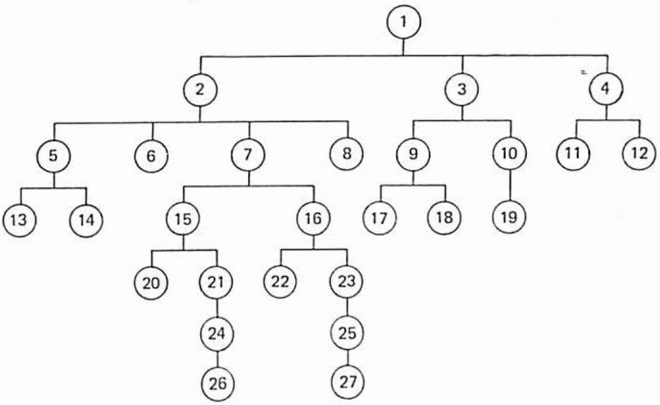


FIG. 27.

The order of learning will be read off this synoptic table, starting with the numbers farthest to the left and lowest on the tree: 13-14-5, because 13 and 14 are necessary for the later acquisition of 5, but not enough to acquire 2: 20-26-24-21 . . . 15; 22-27-25-23 . . . 16; 7; 8; 17-18 . . . 9; 19-10 . . . 3; 11-12 . . . 4; 1. These successions of numbers denote the concepts in Figure 27 and define the order of learning (or teaching). Therefore, here again, ordering the results of analysis is treated as equivalent to determining the order of presentation.

The concepts could however be ordered in several ways. The procedures employed by the analyst may decide in favour of one way rather than another without the reasons being obvious to him or to the subject expert. For this reason we advised against the division of labour between the two.

Once the skeleton flow-chart of our sequence is established, we can embark on the stage of writing the sequence.

Before turning to this stage, it should be noted that *all* the techniques which require at the outset a *behavioural* definition of aims come up against the same difficulties as the two presented here. The reasons are clear: as soon as a teaching aim has been described in terms of behaviour, the problem is how to analyse in these terms what separates the aim from the starting point.

Writing the sequence

After all the preparatory stages or phases, it will be appreciated that the actual writing, the implementation, the task of putting the work into final form constitutes the acid test. And, quite frankly, it is the test for which we are least well prepared. How can we convey the content of the items we have defined? Whether it be visual, verbal, or anything else, their content is being conveyed through a medium which is still, as it were, half-packed. At this point in the programming, we know in principle *what* we are packing up, what each parcel will contain and when we should send it. But how are they to be packed? And how are they to be presented if they are to be willingly accepted?

We are up against all the old problems: logical order and order of teaching, acquired patterns of behaviour, components of knowledge, etc. To face these problems, a critical outlook and a sense of humour are needed.

Whether dealing with a branching or linear sequence, those writing the lesson are advised to pay careful attention to the language in which information is presented, to the form in which the questions are put, and to the nature of the help given to encourage and guide towards the right answers. Word by word, example by example, everything must be carefully weighed and appraised. Experience will quickly show the range of pitfalls which must be avoided, but the mutual criticism which team-work can offer will eliminate many from the outset.

It is always instructive to read programmed lessons written by others, particularly from the point of view of avoiding pitfalls. We recommend such reading for teams who are about to tackle the writing stage; the more one criticizes, the more difficult it is to escape criticism when one's turn comes. It may be charged that it is not enough to warn against the most common mistakes, they should be prevented. For this purpose, the careful study of existing programmes is a good exercise. Whether they are good or bad (the latter are just as instructive), they will give an idea of what should or should not be done. A model is of little value unless we know what criteria must be observed in order to imitate it.

The difficulty of giving the lesson a final form conceals another, far more serious, that of the language in which knowledge is expressed. This must be a natural language, in order to be understood by the pupils; as such, it is not as rigorous as that of the knowledge to be conveyed. Thus a great distance separates the formalized and purely symbolic language of logic from the language which is used for teaching it, and this gives rise to ambiguities which sometimes reflect serious misunderstandings.

Skinner thinks that language is also a 'behaviour', and according to him this difficulty should be examined in the same way as those which are met within other learning processes. In his book *Verbal Behavior*, Skinner puts forward the theory that language learning can, in principle, be subjected to the same types of conditioning as other types of learning. It is this assertion or thesis (which follows ineluctably from Skinnerian principles) that has met with the strongest opposition on the theoretical level, principally from Chomsky [18].

The criticism can be summed up in a few words. In Skinner's view, verbal acquisition depends on the same processes as any other acquisition: a scheduling of reinforcements will result in fixing behaviour. In Chomsky's view, this takes little account of the meaning which words convey and, above all, ignores the way they convey it. The elements of language are finite in number, and yet they are sufficient to signify an indefinite number of facts. We must accordingly assume that language has a 'creative' capacity, which it is therefore impossible in any way to reduce to a set of elements to which operant conditioning could be applied, because this capacity alone explains the fact that the elements are arranged in an indefinite number of patterns [19].

Thus these criticisms bear out what we have said: at the writing stage one has no guide and no protection against the traps of language. How can one engender a cautious and alert attitude? Certain experiments have convinced us that a word-for-word analysis of sequences which have obvious faults is an excellent means of drawing attention to possible pitfalls. Of course it is impossible to ask for an over-all appraisal. What we suggest is a microscopic examination in which every assertion or definition of a concept or of relations between concepts is taken absolutely literally. Such a minute examination very quickly brings out all the illogicalities of thought or expression, and whoever undertakes it will be very wary when his turn to write a sequence comes round.

Against the temptations of facile programming and the pitfalls of language perhaps we need to strengthen our defences; there is no better way to do this than through team-work.

EXPERIMENTAL TESTING: ASSESSMENT AND VALIDATION

At last the sequence has been written, reviewed and its layout arranged by the artist of the group, who has set out the illustrations and the diagrams, chosen the typeface or print in which it will appear, etc. After the final revisions, a number of sequences have been run off, and we wish to test them on a small sample of the intended school population. Many arrangements must be made, of varying complexity depending on the circumstances. If all we want to do is to test the value of the sequence without laying any claim to detailed research, there are very simple techniques and methods. But if we are at all demanding (and why should we not be?) these will seem too simple.

First let us define some terms.[1] 'Experimental testing' comprises the set of trials on the basis of which a certificate of quality will be awarded to the programmed course, allowing it to be used on a large scale in the conditions defined by the certificate. There are two series of tests: 'assessment', which consists of a series of limited tests, followed by the necessary revision; then 'validation', which checks the quality of the product on larger samples taken from the actual environment. Once these tests have been passed, the programmed course is put on the market with a guarantee.

Unfortunately, there are very few programmes which have been subjected to these tests. The procedure is, of course, tedious, but all sorts of other reasons are given for dispensing with it. For this reason great stress should be laid on the need for it, even though in practice there are doubts as to the reliability of the means used for testing.

Assessment

This is carried out with only a few pupils, who are made to study the whole sequence and take all the tests (pre- and post-tests). First they are given the *pre-test*. With only a small number of pupils, it is possible to make some observations while they are working: the time they take to complete the test, the questions which hold them up the longest, etc.

The answers are then studied and compared with the expected answers. Some exercises are designed to test certain prior knowledge (the answers must be correct); others concern the subject under study, and are intended to check that the pupils are not already familiar with it (here the answers should be incorrect or take the form 'I do not know'). It is also advisable to interview the pupils for in this way one can discover the precise meaning of their replies, the difficulty of the questions and particularly, when the answers are wrong, whether the form in which the questions was put should not be reconsidered, etc.

In fact, giving the pupils this pre-test at this stage is only a safeguard, because it was suggested that, in principle, it be given

---

[1] The definitions of these terms vary from writer to writer. We give these definitions for the reader's convenience.

	Frame numbers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Pupils' names	A		●							●								●				●						●
	B		●				●											●				●				●		
	C			●										●				●										
	D		●															●										

Fig. 28. The dots mark the items on which errors were made. The picture they give shows that the errors occurred especially at items 2, 17 and 21. Particular attention will be paid to these items, without, however, neglecting the others.

to a sample of pupils immediately after the objectives had been defined. The reason for giving it to a small number of pupils at this juncture is to ensure that they are at the level of those pupils for whom the sequence is designed. Once representative members of the intended population have been selected in this way, they are asked to study the sequence as constructed.

Study of the sequence. Here too, the behaviour of the pupils should be observed and their reactions noted. When they have finished, we interview them individually and go through the sequence item by item. Errors are entered on a card prepared in advance (on the model of Fig. 28).

Although the errors occur at one point, their cause may lie earlier. The items, then, must be considered one by one, the sample pupils being asked what they think of them: wording, diagrams, layout, examples, etc. This interview is 'clinical' in the sense that it sets out to establish the visible or explicit reactions of the pupils. But it is worth while supplementing it with other questions. We explain to the pupil what we intended and why we went about it in that way, and ask him how he himself would have done it if he had had to give the lesson to his friends. Experience of this type of interview proves that the testing devices are empirical and subjective.

The discussions with pupils on such occasions are always very informative and revealing. The new programmer should be reminded how large a part was played by intuition in his preparatory work, and how little his impressions, however strong, can replace an exact observation which can be checked by others.

The pupils have been questioned one at a time, and their comments, suggestions, explanations and criticisms, etc., have been noted. All these notes have been compared with the hypotheses which were formulated at each stage of preparing the sequence and of which copies have been carefully kept. This comparison is based on the assumption that the pupil is right when he shows lack of understanding or manifests a wish. The next job is to modify the sequence in accordance with the information supplied by the trial. Items which have proved too 'dense' will be split up, some examples will be replaced by others, diagrams will be redrawn and the layout will be altered, etc. I remember a geometry sequence which was intended to give young Congolese the notion of a point. In a so-called 'concrete' example, they were asked what a star suggested to them. The boys unhesitatingly answered 'a point', as had been intended; the girls, on the other hand, talked of diamonds, jewels, rings or gold. The example and the question, obviously, had not succeeded in arranging the 'reinforcing contingencies' in the way expected; something less evocative, though no doubt duller, had to be found.

The phase in which pupils are redirected and corrected is a key phase. But it is productive only if we have been able to formulate hypotheses implied by completion of the previous stages. For this is the point where our choice of the previous stages is justified, the moment of truth. If we have been too hasty in relying on the results of the first trial for the purpose of making any necessary corrections, we shall not be able to use those results, not knowing what they should be compared with.

The corrections are made and the new version of the sequence is prepared.

Another trial is set up with a new group of pupils, using the same procedures. The method is basically one of successive approximations, oddly reminiscent of the trial and error method used by Thorndike's rats.

Each time a trial is made, the selected pupils are also put through the *post-test*. There are two aims in trying out this test and they are, in fact, contradictory: in the first place the test must check that the sequence has been understood; yet in addition we want to test whether a proper check can be made by this means. We want the test to check the validity of the sequence, at the same time as we are attempting to test, by reference to the sequence, whether it is a good checking instrument. The fewer precautions one has taken in advance in setting up such a test, the more risky it is.

Remarks. Although experimental tests are not difficult to carry out, the work of setting them up should not be treated as a matter of secondary concern. This, however, is usually what happens. Such is the fascination of matrices, trees and graphs, so exciting is the actual writing of the programme, that the appointment with the pupils is forgotten. We need hardly remind readers that all the stages of programming should be directed towards keeping this appointment.

Interpretation of the results of these trials will in any case depend on strict concern in this regard. If other interests have claimed one's attention, these other interests will determine the way one analyses the answers, questions the pupils and later corrects individual items. Thorndike's rat used to get an electric shock when it went the wrong way!

The sequence and the tests have been duly revised and corrected, and are now complete; the last sample of pupils has shown that both sequence and tests were satisfactory. A new trial is necessary, with another, larger batch of pupils, which should be representative of the intended population as a whole. The last tests before putting the sequence on the market is that of validation.

Validation

The purpose of validation is to check that the sequence is indeed suitable for as many pupils as it is intended to teach. To this end it must be tried out on a larger number of pupils, representing the variety which may be met with.

Comment. The distinction between assessment and validation which is made here rests on the fact that the purpose of the former is to obtain the sequence which the programmer wants, that of the second to see whether such a sequence is suitable for the pupils. The distinction may at first seem academic, but it is justified by the reflection that the sequence made will be effective when it has also proved its efficiency—that large numbers of pupils can study it [20].

The most important operation is to determine the sample. In planning and carrying out such sampling, the help of a psychologist is indispensable, since he has at his disposal a whole armoury of techniques which can be used as a guide when deciding on the factors to be considered in the selection. In principle, little is asked of him; if the objectives and the tests have been drawn up in a completely operational manner, his technical contribution will be confined to the material planning of the sampling operations using the two tests. In practice, when we consider the total number of unknowns, and the number of hypotheses which have been built up during the planning of the sequence, we shall be obliged to ask more of him. Our instruments are too fragile to obtain a satisfactory sample, and we shall have to achieve this with other instruments which have already proved their mettle.

The psychologist can draw on his repertoire of tests to find those which are best suited to the programmer's needs: intelligence tests, attainment tests, tests of pupils' reasoning powers, their vocabulary, their socio-cultural characteristics, etc. [20]. But the characteristics of the population will have been defined at the very beginning of the programming process, and the psychologist, therefore, present since the beginning of the group's work. He will have intervened to ask what characteristics of the population are to be taken as a basis for subsequent use. Next, working within his own field, he will choose the proper sampling tests, and indicate how they are to be applied. The choice of methodology is then a matter for the psychologist,.not for the teacher-educator or the teacher, who will accordingly not be concerned with the details of the techniques which the psychologist uses. What is important is the type of co-operation which must be established between the psychologist and the teachers who are writing the programmes. The former should not use his tests to impose any preconceived form or content on the sequence. Conversely, the teachers will not force him to devise 'made-to-measure' tests intended to prove what they wish to prove. Unless real team-work is achieved, the successes the process will produce will be highly suspect.

Once a group of pupils representative of the whole population has been selected, this group can be used to simulate actual study and working conditions. As in the case of assessment, the pupils are first given the revised pre-test, then the sequence and finally the post-test. These three operations can be carried out on different days. Here again, it is interesting to observe pupils' behaviour. But teachers come up against one particular difficulty. They are reduced to a passive role, and it is often difficult for them to resist the temptation of intervening or 'invigilating'. This prejudices the experiment, in the sense that the pupils do not feel that they are working alone with their programmed lesson. And perhaps, just because they feel they are being watched, they will be afraid of making mistakes and will check on the right answer before giving theirs. For this reason teachers keep a neutral attitude, and tell the pupils that if they make mistakes it does not matter.

It is also important to note the time each pupil spends learning the lesson, because it would be dangerous to give them unduly long sequences. The concentration required by the study of these lessons is such that it cannot be kept up for too long without breaks occurring in the pupils' progress, which may subsequently hinder their understanding.

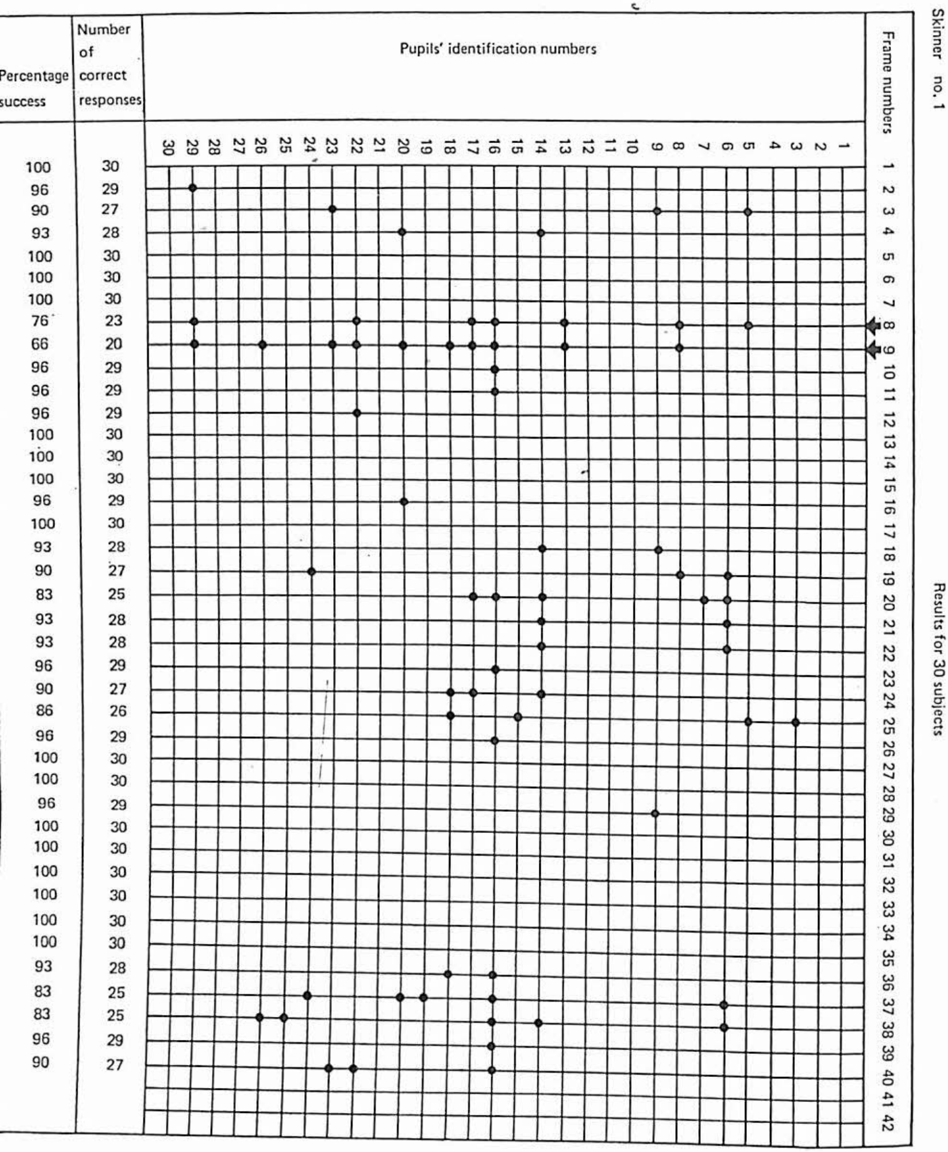
Once the sequence has been learnt, the answers given by each pupil to each item are studied. A table is used on the lines of that in Figure 29; the mistakes made are indicated by dots. Pupil No. 1 made no mistakes; pupil No. 14 made 7 and No. 16 made 12. At the foot of the columns the total number of correct answers to each item has been entered and underneath, the percentage of success. The information given by this diagram has been reproduced in Table 3.

How is this data used?

First of all, it gives us information on the location and relative frequency of mistakes. Items 8 and 9, for instance, have occasioned 7 and 10 mistakes respectively. In the case of the pupils, also, it can be seen that two of them (14 and 16) have made many mistakes. This is not enough to indicate the causes of these mistakes, and how the sequence should be corrected. In order to achieve this, we need the documentary material prepared during the process of programming.

Items 8 and 9, for example, refer to ru 3 of the Davies matrix, and to some columns of the flow-chart, or alternatively to the third stage of behavioural analysis. Reference to one or other of these will give us a better idea of the causes, for we can see what content is involved, the procedure chosen to teach it and its relationship to other concepts. In this way, we see that ru 3 and ru 12 are linked, and that the items which expound them are 8, 9 and 37-38; it is also precisely at these points that there are clusters of mistakes.

This may help us to formulate the first tentative hypotheses on the causes of these mistakes. The results obtained from the pre-test will perhaps show that the concepts in question require prior knowledge which not all pupils possessed. Are these the ones who made the mistakes? Here we see the reason for stressing the need to preserve all the documentary material prepared, since it provides us with a basis on which to work when considering what hypotheses are to be formulated. But this material is often not enough; the only way out, in that case, is to question the pupils, suggesting that they should put forward other types of presentation which seem clearer or more comprehensible to them.



Skinner no. 1

Results for 30 subjects

Percentage success	Number of correct responses	Frame numbers	Pupils' identification numbers
100	30	1	
96	29	2	29
90	27	3	23, 9, 5
93	28	4	20, 14
100	30	5	
100	30	6	
100	30	7	
76	23	8	29, 22, 17, 16, 13, 8, 5
66	20	9	29, 26, 23, 22, 20, 18, 17, 16, 13, 8
96	29	10	16
96	29	11	16
96	29	12	22
100	30	13	
100	30	14	
100	30	15	
96	29	16	20
100	30	17	
93	28	18	14, 9
90	27	19	24, 8, 6
83	25	20	17, 16, 14, 7, 6
93	28	21	14, 6
93	28	22	14, 6
96	29	23	16
90	27	24	18, 17, 14
86	26	25	18, 15, 5, 3
96	29	26	16
100	30	27	
100	30	28	
96	29	29	9
100	30	30	
100	30	31	
100	30	32	
100	30	33	
100	30	34	
100	30	35	
93	28	36	18, 16
83	25	37	24, 20, 19, 16, 6
83	25	38	26, 25, 16, 14, 6
96	29	39	16
90	27	40	23, 22, 16
		41	
		42	

FIG. 29.

TABLE 3

Percentage of correct answers, by item			Percentage of correct answers, by pupil		
Number	Percentage of success		Pupil's identification number	Percentage of success	
1	100		1	100	
2	96		2	100	
3	90	×	3	100	
4	93	×	4	100	
5	100		5	95	
6	100		6	85	—
7	100		7	100	
8	76	—	8	97	
9	63	—	9	95	
10	96		10	100	
11	96		11	100	
12	96		12	100	
13	100		13	100	
14	100		14	87	—
15	100		15	97	
16	86		16	72	—
17	100		17	95	
18	93	×	18	95	
19	90	×	19	100	
20	83	—	20	95	
21	93	×	21	100	
22	93	×	22	90	×
23	96		23	92	×
24	90	×	24	100	
25	86	—	25	100	
26	96		26	97	
27	100		27	100	
28	100		28	100	
29	96		29	97	
30	100		30	100	
31	100				
32	100				
33	100				
34	100				
35	100				
36	93	×			
37	83	—			
38	83	—			
39	96				
40	90	×			
41	95				
42	86	—			

Level (threshold) of validity: 95%
At this level: 60 mistakes
'Excess' of mistakes: 8

Threshold > 90 < 95% → ×
Threshold < 90% → —

Threshold < 90% → —
Threshold > 90% < 95% → ×

Over-all percentage of the sequence:
Total number of items, 1,200
Total number of mistakes, 68
Percentage of success, 94
Average of correct answers, 39
Average of mistakes, 1

Over-all percentage after eliminating numbers 14 and 16
Total number of items, 1,120
Total number of mistakes, 49
Percentage of success, 95·7%

The post-test, which will have been given after the sequence, can also be instructive and may furnish other indications. Using this material, we must now deduce the corrections which will be made to the programme.

Remarks. Some surprise may be felt at the primitive nature of the statistical instruments which have been applied, since we confine ourselves to establishing percentages and derive from these a success rating which is then compared with the target we had set ourselves. If 95 per cent of pupils answer 95 per cent of the questions correctly (in the case of a linear programme), or 70 per cent (in the case of a branching programme), the sequence is deemed 'valid'. These are over-all figures, and may hide unsuspected facts. In the example chosen, two pupils and two items are involved, but if we do not take these particular pupils into account the success rating is 95.7 per cent, which would entitle us to conclude that the sequence is right, and to ignore the two items which are shown to be at fault.

When the over-all percentage alone is given, then, it may present a false picture of the quality of the sequence; we should be wary even of the way in which it is calculated. All the items are put on the same level, as are all the questions in the tests: they are given the mark either of 1 or 0 (right/wrong, and if we try marking we shall soon see there can often be hesitation between 1 and 0). Moreover, there is little sense in adding up the results expressed in this form: this means adding up successes which do not all have the same value and then using these totals to trace the mistakes.

To a large extent, the criticisms directed at the above assessment and validation techniques are well founded. Attempts have been made to refine them, especially by using more advanced statistical methods. The results are not convincing; a more rigorous approach is needed in organizing the subject-matter and, subsequently, in regard to the items of behaviour involved in the sequence. In the present state of research work, this is not yet possible. The large number of variables, the complexity of the situation and the difficulty of experimenting are the main obstacles.

This does not mean that such techniques have no application. Even if they do not yet meet the demands of a strictly scientific approach, they can instil a concern and a desire for such an approach. To this extent they can be of great formative value.

SECTION 2. THE NEW TECHNIQUES

As proposed at the beginning of this chapter, the 'new' techniques are here being discussed as a separate category with this label because they break with the Skinnerian tradition. Perhaps this does them too much honour, because they have hardly been codified at all and are for the most part not in widespread use. Information about them is in any case scattered, incomplete and difficult to compile. Here is proof of the multiplicity and vitality of the research effort inspired by programmed instruction. Although the 'new' techniques are still evolving and therefore difficult to describe, it is interesting to observe that a non-behaviourist type of programmed instruction is being developed. Even if it is impossible to describe these techniques, it is useful to know along what lines and in what direction they are moving. Let us say very briefly that what they have in common is a concern with what goes on in the 'black box'.

The most original research has been undertaken in the United States and the Soviet Union.

SUPPES

Speaking at a symposium [21] at which he presented his work, Suppes affirmed:

> *My original title for this paper was 'Behavioural Foundations' rather than 'Psychological Foundations'. The reason for changing is the desire to avoid the charge of attempting to reduce mathematics to the kind of consideration exemplified in Skinner's* Verbal Behavior. *Moreover, it is an increasing conviction of mine that the classsical concepts of behaviourism, namely those of stimulus, response and reinforcement, are not, at least in their standard formulation, nearly adequate for any complicated behaviour, and in particular for the intellectual activity of mathematicians and scientists.*

The extent to which Professor Suppes is moving away from behaviourism and the Skinnerian ideas could not be clearer; even the title of his paper is an illustration of this. Furthermore, he very clearly asserts that 'intellectual activity' is, in certain areas, not capable of being reduced to components of behaviour described in terms of stimulus, response and reinforcement. The idea of intellectual activity apparently takes us back to notions which we had exorcised by enclosing them in the 'black box'; we have now reached the time for experiments and the question is perhaps due for reconsideration. Professor Suppes says in effect that certain mathematical activities cannot be analysed in operational terms. Behavioural analysis, therefore, does not successfully account for them, and this is proved by experience:

The first thing to be noticed in considering the question of what does the theory say about the formation of new concepts out of old ones is that many details of the learning process are irrelevant. For example, for analysis of this problem it is not essential to know whether learning is mainly all-or-none or incremental [22].

Suppes thus observes that the very nature of mathematical concepts cannot always be conveyed exactly in the terms which Skinnerian behaviourism imposes. He also picks out another shortcoming:

The second thing to note is that unless the theory has sufficient apparatus for defining new concepts in terms of old ones, the theory cannot give a systematic account of how the new concepts are learned [23].

Thus he feels that modes of learning new concepts cannot be based on the contents by which former modes were determined. But surely, according to the Skinnerian thesis, the old concepts are precisely the ones on which one can act to induce the acquisition of new ones. This idea, then, is questioned and criticized. In the last resort, what one wishes to teach in mathematics is *something other* than those parts of the subject which can be reduced to patterns of behaviour. A new concept is not acquired only on the basis of other concepts which one already possesses. What then would be the use of relying solely on the latter to prepare people to understand new ones?

If these comments are fair and well founded, the determination of 'objectives'—the first stage of programming—takes on a different meaning. The problem becomes one of defining these objectives in terms of 'psychological' requirements, and not in terms of behavioural ones only. Thus, after noting that traditional theories of learning are incapable of affording an understanding of mathematical concepts, we find the whole problem of what learning should involve presented in a new form. The first task is to shed light on the mathematical notions and relations and, at the same time, on the processes whereby they are assimilated.

Suppes shows for instance how the teaching of addition necessarily brings in the properties of associativity and commutativity. But in order to allow for these, the psychological characteristics of the process of learning them must also be taken into consideration.

This approach is quite different from that of behaviourism: the mathematical concepts are acknowledged as part of a reality which is not simply the reality of the way they are learnt. On the contrary, their 'bases' are sought at the level of 'psychological' activities. Consequently, the analysis of contents must be considered in a different way and must involve new techniques. We have not yet reached the point where we can develop these, but they are certain to take us inside the 'black box'.

For the time being all this is 'for information only'. However, it is interesting for teachers to have some idea of research in progress. A study of documentation on this subject makes a good subject for a seminar in which current problems and experiments are considered and discussed. The group is certainly the right unit in which to gather and give out such information. The increased diversity of the experimental and research work which programmed instruction is now stimulating makes it impossible to give a synoptic picture of what is being done. There is in fact so much research and experiment that to catalogue and take stock of them have themselves become subjects of research and inquiry.

THE SOVIET SCHOOL

In the Soviet Union there is a long tradition of research into the learning process and the application of such research to teaching. From the outset programmed instruction aroused great interest among educationists, research workers and officials.

An expert report [24] has noted the strange similarity of the approach adopted by British and American experts on the one hand and Soviet experts on the other. Pragmatism prevails. However, a few teams have got down to basic research resulting in the formulation of theories and the development of new techniques. The most progress seems to have been made in the project undertaken by Professor Landa and his fellow workers. The lack of documentation, more specifically translations, means that our information on the subject is for the most part late and incomplete. Therefore we cannot be sure that any picture we can give of such research findings faithfully reflects the state of the art. We shall attempt to describe the work done by this team or rather the theoretical bases which this work has enabled them to define [25].

'*The critique of behaviourism as a theoretical basis of programmed instruction*' [26]

Behaviourism is mainly criticized for 'proceduralism' and 'biologism'. It is alleged that the 'stimulus-response-reinforcement' scheme results in a refusal to consider psychological facts as a specific reality. Behaviourist analysis is criticised as 'proceduralist' or mechanistic because it converts the results of applying the laws of behaviour into fundamental principles: there is some effect, and from this the inference is made that behaviour is subject to the law of cause and effect as if this explained everything. It is 'biologistic' because the descriptive scheme which it puts forward is assumed to represent all the modalities whereby a living being adapts to its natural environment.[1] Behaviourists have forgotten that human behaviour, its origins and its characteristics, can be grasped only as specifically social facts and that it is therefore not legitimate to extrapolate phenomena from the animal kingdom to man.

Expressed in these terms, the criticisms are not really convincing: they merely illustrate in the form of general statements, the difference between two systems of working hypotheses. To interpret them from an epistemological point of view will be hardly more illuminating until we know the kind of methods or techniques used in the search for reliable arguments.

The basic notions of learning

In the first place, these notions stress the importance to be given to 'internal psychological mechanisms'. When the pupil is given a problem to solve, he may arrive at the right result, which constitutes the 'correct final behaviour'. But the pupil may have arrived at this result by chance, by feeling his way, by using a lucky analogy, or methodically (and even then there are sometimes several methodical ways of arriving at the same result). Conversely, the pupil sometimes shows himself capable of finding the solution to some problem methodically, and yet incapable of finding the answer to some other, similar problem. The mere test of final behaviour is insufficient to explain such phenomena. Therefore it cannot provide us with the means of avoiding them or causing them. If so, it is inappropriate and dangerous to set instructions for the aim of obtaining specific final patterns of behaviour. On the contrary, what we should try to programme are the methods or operations by which such behaviour is achieved.

Therefore attention is concentrated on what N. L. Landa calls the 'internal mechanisms' of mental activity. This implies a shift in the aims of instruction: these are now determined by the relationships existing between such mechanisms [25].

---

[1] The few sources which we were able to consult (articles, books and bibliographies) seem to indicate that Soviet scientists are as badly informed of behaviourist work as we are of theirs This is borne out by comparing the critique of B. F. Talysina [26] with the book by M. Richelle entitled *Le Conditionnement Opérant* [27].

This is the key problem facing the teacher and the writer of the teaching programme: his concern is not so much to induce and fix specific manifestations of some given behaviour, but also and above all to bring into being precise mechanisms, sufficiently generalized and reliable, which are capable of producing such behaviour whenever required [25].

In order to describe and bring into being such exact, general and effective mechanisms, these will be expressed in the form of 'algorithms'.

Algorithms are descriptive working models of the solution of specific problems. 'Descriptive' because they make explicit the methods, choices and criteria to be taken into account in order to arrive at the solution of a given problem; 'working' because, once made explicit, they become instruments for discovering the solution.

When the word algorithm is used in this way, it has not quite the same sense as that given it by mathematicians or data-processing experts, though it owes a lot to them. For mathematicians, an algorithm is defined thus:

By algorithm is meant a precise instruction to carry out in a specified order certain related systems of operations for the solution of all the problems of a given type [28, p. 5].

. . . *In mathematics, a series of problems has been solved when an algorithm has been set up for the solution of each problem in the series* [28, p. 9].

Data-processing experts, on the other hand, give the following definition of the word:

By algorithm is meant a plan for analysing a function, developed in the form of a succession of elementary operations, each taken from a fixed set [29].

Landa and his fellow workers use the same word to describe a series of intellectual operations linked together in a manner which depends on the material to be dealt with and the decisions to be taken. Thus the elementary operations of the data-processing expert or his mathematical colleague are equated, in Landa's definition, with the steps which constitute the elementary operations of problem-solving. Table 4 gives as an example the general algorithm for recognizing a Russian sentence and, more precisely, for identifying whether it is a simple or compound sentence. Although this is a simple example, it does show that there are several reasons for calling a sentence a simple or compound sentence, without counting the spurious reasons, which the table does not show.

Shall we teach pupils how to make this distinction? This can be done by instructing them in the algorithm shown here. Let

TABLE 4. Algorithm for the recognition of a sentence (in Russian)

Problem

Is it a compound sentence or a simple sentence with equal constituents?
In order to determine the type of sentence, we must:

1. See if there is a subject
   - **Yes**
     - 2. Find all the predicates
     - 3. Determine whether all the predicates apply to one and the same subject
       - **Yes**
         - Conclusion *Simple sentence*
       - **No**
         - Conclusion *Compound sentence*
   - **No**
     - 2. Find all the predicates
     - 3. Determine whether all the predicates are first- or second-person verbs
       - **Yes**
         - Conclusion *Simple sentence*
       - **No**
         - 4. Determine whether all the predicates are verbs in the third-person plural
           - **Yes**
             - 5. Determine whether several people are involved in the action of the sentence
               - **Yes**
                 - Conclusion: *Compound sentence*
               - **No**
                 - Conclusion: *Simple sentence*
           - **No**
             - Conclusion: *Compound sentence*

us consider this assertion for a moment in order to see what it means for the teacher. First, the teacher must set up the algorithm or algorithms of the activity he wishes to form; but if he is to be quite certain of achieving this, this algorithm will have to be taught to the pupils. The object is no longer simply to arrive at the correct *results;* it is first and foremost to train pupils in the *operations* which produce these results.

Remark. The idea of including the learning of such algorithms among the aims of instruction often appeases those opponents of programmed instruction who accuse it of paralysing creativity, in the sense that it communicates only accepted solutions. It may be argued then, that if we teach methods rather than solutions, we are at last making room for creativity. Readers of Descartes see the contrast here in terms of an 'analytic' development which, whether linear or branching, excludes any inventiveness, and its replacement by a 'synthetic' development which gives scope to the creative spirit. The criticism is usually directed against the techniques we have called traditional, but it also arises with regard to the 'new' techniques. In this way an analogy is even drawn between our methods' highly detailed spelling-out of the content (by seeking the elementary units of information) and the Cartesian idea of seeking simple ideas; and on this basis the claim is made that programmed instruction is putting into practice in teaching the ideals of the *Discourse on Method.* Nothing could be further from the truth!

The *Discourse on Method* teaches us how to 'conduct our thoughts aright'. But this does not mean *conducting* them in the attempt to reconstitute a train of thought which has already been worked out, as when we repeat the proof of Pythagoras' theorem. Descartes set himself no smaller task than the reconstruction of the whole edifice of knowledge on the basis of reason. His method, then, is directed not only towards a re-examination of the store of knowledge which has been built up, but also towards orienting new research; it is thus intended as a method of discovery. The second rule of method defines 'analysis' as follows:

. . . *divide each of the difficulties which I was considering into as many parts as was possible and necessary in order the more readily to solve them.*

If we take this rule literally as it is formulated, we might be tempted to think that this is what programming attempts to do when it 'organizes the subject-matter in logical order', or 'analyses the contents'. This is a complete misinterpretation. The search for *elementary units* of information is intended to discover what is simple for the pupil; but the search is carried out by the programmer in order to spare the pupil the effort of this analysis. In fact what the pupil is asked to learn is a mere exposition of the 'synthesis'. Indeed, the fourth rule on which Descartes decided was:

> *. . . everywhere to carry out such complete enumerations and general reviews that I could be sure nothing had been omitted.*

This is exactly what we advise should be done after the analysis of contents. In other words, this work is not given to the pupil; instead, he receives a ready-made 'synthesis'. The reference to Descartes, then, is a complete mistake in historical terms and the man who suffers most is Descartes himself, since his authority is invoked to justify procedures which he criticized before putting forward his rules on method.

The invention of solutions is the job of the programmer himself. All the pupils learn is a range of ready-made strategies by which such solutions can be found. In other words, they do not do the work of analysis (in the Cartesian sense): what they are taught is the synthesis already achieved. This is apparently what Landa and his team are attacking:

> *The aim of teaching algorithms should be*, inter alia, *to introduce pupils to algorithms and other common, sufficiently general processes of ratiocination or other intellectual activity applicable to a variety of scientific subjects and fields* [30].

On the basis of these aims, programming is set the following targets:

To formulate the algorithms of the pupil's intellectual activity for a given subject; these should be expressed in terms of 'common, sufficiently general processes of ratiocination . . . etc.'

Since for any particular subject, it is possible for pupils to act on algorithms which are non-specific, not general enough or inconsistent, these should be traced and subsequently corrected.

To check that, allowing for the forms of the pupils' intellectual activity, the instruction they receive adapts the 'normative' (theoretical) algorithms which they are to be taught to those they use in practice.

The stages of programming

These comprise, first, 'discovering the internal structures of the mechanisms of thought, and describing these in the form of algorithms' . . . 'Presenting them in the form of models, will in itself provide a *guiding thread*[1] running through the teaching . . .' [30].

The first task, then, has the effect of spelling out the intellectual operations required for the solution of specific categories of problem. This is content analysis of exactly the same type as that used in the traditional techniques. Therefore, during the process of analysis the same difficulties mentioned in connexion with the latter group of techniques can be expected to arise: the reactions motivated by over-all attitudes are more than likely to crop up here in similar guise. To meet them, however, stress should be laid on the specific aspects of the content analysis which we now wish to undertake. Let us take a famous example which has led many new programmers astray: the agreement of the past participle in French. It is perfectly feasible to teach the relevant rules one by one and stage by stage, but the pupil faced with a given case calling for such agreement is in a special situation. It is not enough that he should know the rule which applies for us to be sure that he will use it correctly; he might also apply it in cases where it is not appropriate. We shall have established that he knows how to make agreements if, faced with any instance of the problem, he can find the right rule. Therefore he must master all the rules, that is, have at his command criteria which he can use to discover, with the minimum number of operations, the rule which applies. Consequently the aim of instruction is to teach the whole of the algorithm describing the operations to be carried out, the order in which they should be effected, and the criteria to be applied. The description of objectives, of the type of intellectual activity to be taught, thus merges with the analysis of the contents of teaching.

---

[1] Author's italics.

How can the model of the activity in question be expressed in the form of an algorithm? We should first point out that an algorithm is a 'representation of the internal structures of the mechanisms of thought' [30]. Each of the branches (see example above) corresponds to a choice to be made on the basis of a criterion or condition. If the condition is fulfilled, a check is made on whether the next is fulfilled, and so forth. Scanning for whether a condition is or is not fulfilled constitutes an operation, an 'intellectual mechanism'. This is why the algorithm develops in the diagram like a tree with bifurcating branches: each operation is a choice between two alternatives (Fig. 30).

Let us imagine we are dealing with this problem of the French past participle. The first question to be asked is whether it is conjugated with the auxiliary *être:* the answer must be yes or no. If yes, the next question may be: Is there a direct object? And so on.

Every question involves a criterion by which a choice is made, and according to the reply chosen, leads on to the application of some other criterion.

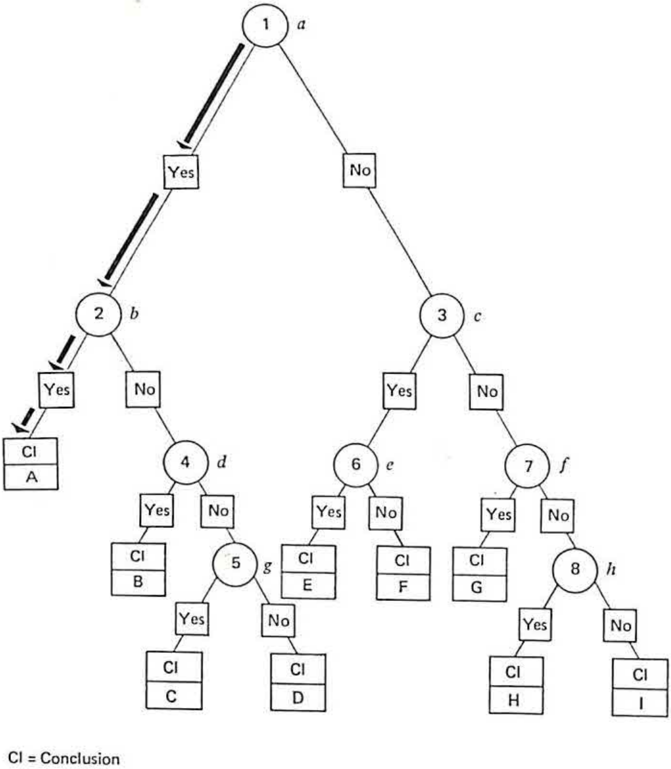


FIG. 30.

In each case, a number of criteria must be tested before one can conclude that the condition in question is fulfilled. Whenever a condition is fulfilled, it represents a 'characteristic of the object'. Let us assume that the applicable rule is rule A for participial agreement. In this case we have to put questions 1 and 2 and end up at A (see Fig. 30).[1] To reach that point, we shall have had to check for the presence of characteristics *a* and *b*; we then write out the participle with the appropriate ending. That is the final act, called R. We can see that *both a and b* are required if action R(A) is to be adequate.

---

[1] Author's note: Figure 30 obviously does not represent the algorithm for agreement of the French past participle.

By using a logical operator meaning 'both' and written '&' this action can be expressed by the formula:

$$a \,\&\, b \Rightarrow \mathrm{R(A)}$$

which may be read as follows:

'*If* one has both *a* and *b*, *then* one must carry out operation R(A).'

In each case, it is possible to set down a similar formula, expressed as one set of circumstances entailing another. It is then possible to summarize in a single formula the full set of actions $\mathrm{R}(x)$ which the algorithm comprises, together with the characteristics to be taken into consideration. This formula may for instance look like this:

$$a \vee b \vee c \vee d \vee e \vee f \vee g \vee h \Rightarrow \mathrm{R}.$$

The symbol $\vee$ represents a variable which can be replaced by either & ('and': both . . . and) or $\vee$ ('or': either the one or the other, or both).

Before we can set down such a complete formula, two operations will have to have been carried out: (a) identifying the criteria or characteristics of the objects which will guide the actions; (b) putting them in order.

The identification of characteristics. There are no norms here either; and we are in the uncomfortable situation of seeking criteria in a systematic way, without having available any prior criteria to enable us to proceed scientifically. We therefore have to feel our way and consider the subject selected, trying to spell out the actions by means of which we can go straight to the solution. It is the job of the teacher to express clearly the rules of participial agreement point by point, and how he goes about it. The only guidance we have is provided by the actions which we wish to see the pupils carry out; these are in fact the actions which we ourselves carry out without always distinguishing them clearly. Spelling them out again requires group work, the best remedy against any uncertainty there might be about methods.

Once the *criteria* or the *characteristics* have been enumerated, the actions which apply to them must be *put in order*. This ordering has several purposes: to put them in some kind of order, certainly, but also to find the 'economical' order. Indeed, once the criteria to be applied have been chosen, it is possible that more than one ordering will account for the processes which they control. Since some of these comprise more operations than others, we have to find the most economical.

Remark. It is worth stressing this concern with the economy of means. Landa draws attention to the immense waste of intellectual energy entailed by the repetition of useless operations in the solution of everyday problems. The cause is the use of overcomplicated algorithms; but the responsibility for this falls on those who allow them to take root without checking them. In the last resort, Landa wishes to concentrate on learning the fundamental mechanisms of intellectual activity, i.e. the formation of logical operations (cf. Talysina, Halperin and others).

Landa has proposed a whole series of techniques, based on cybernetic data, for ordering the operations. Their underlying principle is as follows: if I have to find out something and a number of operations are necessary for me to do so, I shall get on more quickly if each operation eliminates the largest possible number of unknowns. A pupil faced with a problem is in the same situation. And the programmer who is going to help him solve it must 'weigh' (or 'weight') each operation involved. The goal is reached more or less directly according to the order in which the operations have been linked together in the algorithms. The principle of economic ordering is thus immediately apparent: those pieces of information which eliminate the largest proportion of what is unknown must be put first. Criterion *a*, say, yields more information than criterion *b*; however, placed elsewhere in a whole list of criteria, *a* may yield less placed before *b*, *c* and *d* than after *b* and before *c* and *d*.

It can immediately be seen that the choice of the initial question has definite consequences for what follows. The amount of information yielded by a criterion depends on its position relative to the others. Landa thought this could be measured by employing procedures suggested by information theory [31]. Such procedures however, are relatively complex and unwieldy. Although research is being done on them, they do not yet lend themselves to systematic application.

The *second stage* in programming is more original and breaks new ground. It consists of an inquiry into the mistakes or errors regularly made by pupils in the process of learning a given subject-matter. For this purpose, pupils making these mistakes are asked to complete a questionnaire; the questions are framed so as to identify the criteria on which they have based their answers. Several explanations are possible: perhaps the criteria have not been understood, or possibly others have been used which are inadequate for the purpose. It is this second case with which we are concerned. Taking one of Landa's examples, let us assume that the correct action is described by the following formula:

$$a \mathbin{\&} b \mathbin{\&} c \Rightarrow \mathrm{A}.$$

If some pupils also regard criterion d as relevant to solution of the problem, their answers will take it into account; and the action which these answers constitute should be described by a formula in which d appears. We thus possess the basic elements enabling us to list all possible mistakes. These elements are: the absence of one or several criteria (denoted by a line placed thus: $\bar{a}$ or $\bar{b}$); and the use of irrelevant criteria d. We are then in a position to list all possible combinations:

$$\begin{array}{cccccccccc}
a & b & c & d & & & a & b & c & \bar{d} \\
\bar{a} & b & c & d & & & . & . & . & . \\
a & \bar{b} & c & d & & & . & . & . & . \\
. & . & . & . & & & \bar{a} & \bar{b} & \bar{c} & \bar{d}
\end{array}$$

With n criteria, there are 2^n combinations. Of these, some are absurd: $a\ b\ c\ d$, for example, is meaningless. These meaningless combinations can be eliminated, since they correspond to mistakes which are never made. The remaining combinations represent the possible mistakes. That is not to say, of course, that they all occur. A questionnaire (a test) is drawn up to check and identify the mistakes that actually occur.

This process leaves us with a list of mistakes actually made, together with their characteristics. The following formula can be used to show all the actions carried out by pupils on the given subject:

$$a\, b\, c \vee a\, b\, \bar{c}\, d \vee a\, b\, \bar{c} \vee \ldots \Rightarrow \mathrm{A}.$$

The above formula is a condensed representation of all the actions (and the criteria governing them) which produce behaviour of type A in the pupils.

Considerable importance is attached to searching for and identifying mistakes. Programming is not used merely as an aid to learning, but also to identify and correct mistakes: in the author's words, it has a *therapeutic* role. How does a lesson fulfil these two roles?

The elaboration of the programmed lesson

The principles involved are simple. The lesson must present information and determine for each pupil the intellectual mechanisms guiding him during the learning process. To be more precise, the formula governing his actions has to be identified: it might, for example, be $a\,\bar{b}\,c\,d$ or $\bar{a}\,b\,c$. The purpose of the exercises presented in the sequence is to identify the formula representing his intellectual activity. The exercises are thus used for two purposes: first, to provoke a certain activity in relation to the information supplied, and then to check the nature of the activity, i.e. the criteria that direct it. Once the type of activity in question is recognized, therapy can be used. If, for example, the pupil's behaviour corresponds to the formula $a\,\bar{b}\,c\,d$, we would then know that it is criterion b which he has overlooked and which he must learn; and, similarly, that the irrelevant criterion d must be dropped. Following this diagnostic, he is taught the correct algorithm represented by the standard formula: $a \,\&\, b \,\&\, c$. This can be equally well expressed by a diagram similar to that used in Figure 30.

In form, the lesson resembles a branching programme. Professor Landa points out that many of the preparatory operations (such as deriving and analysing the formulae) can be performed by a computer. This ability to automate the error-spotting and teaching functions seems to him to promise spectacular developments.

CONCLUSIONS

The spirit in which Landa and his Soviet colleagues are carrying out their research work demonstrates their concern for the study of intellectual and cognitive processes. The relationships which they establish between the structures of logic and psychological mechanisms are characteristic of the non-behaviourist influence currently prevalent in programmed instruction. In the realm of applications and techniques, work still remains to be done; however, the results of the experiments that have been carried out seem particularly fruitful. Accordingly, while referring to the principles underlying the current attempt to improve techniques, we have laid less emphasis on the techniques themselves.

This section has presented certain lines of research in regard to the new techniques. There are many other approaches, but they are difficult to classify since the research in question is still under way. It is, however noticeable that all these approaches have a common preoccupation with increasing our knowledge of the learning processes and with developing teaching instruments better adapted to the pupil's needs. However, with the exception of some infrequent efforts, it must be said that epistemological considerations are still treated as either secondary or superfluous.[1]

The problems raised by the methodology of programming techniques (whether traditional or new) do, however, demonstrate the importance of such considerations. If the language employed to convey those notions already analysed risks distorting the message—if, for example, it conveys unintentional connotations—the experimental results will be difficult to interpret. But the most serious error would be to continue to rely on techniques simply because no attention has been paid to those factors which the techniques do not take into consideration. For the purpose of preparing teachers to give epistemological questions due consideration, it is preferable to present teachers with a critical review of outstanding problems. The experience of instructors shows that teachers are grateful to them for this and that many initial over-reactions are thereby avoided.

It could be argued that up till now the advantages of programmed instruction appear to concern mainly student teachers and research workers. But what about the pupils? And what of the application of programmed instruction in school? Such an objection is valid, but only up to a certain point. It is highly unlikely that teachers who were ill informed could write good programmes—in which case the pupils would be the first to suffer. It is therefore essential that teachers should be well informed. And if, in the process, they can get an insight into the problems on which the research workers are engaged, all the better, since this will make it possible to initiate a dialogue between the two.

REFERENCES

1. See section on programming techniques in 'Further reading', p. 178.
2. LETERRIER. *Programmes et instructions. (Ecoles maternelles, primaires, CEA)*, p. 130-1. Paris, Éditions Hachette.
3. SKINNER, Burrhus, F. *The technology of teaching*. Chapter IV. New York, Appleton-Century-Crofts, 1968.
4. ibid., p. 59.
5. ibid.

---

[1] J. Perriault (Maison des Sciences de l'Homme, Paris) is currently attempting to develop a technique or content analysis giving a prominent place to such considerations. A book setting out this theory should be published shortly.

6. Battro, Antonio, M. *Dictionnaire d'épistémologie génétique*, p. 124. Paris, Presses Universitaires de France, 1966. (Études d'épistémologie génétique, 21.)
7. Migne, J. Les obstacles épistémologiques et la formation des concepts. *L'éducation permanente*, no. 1, March 1969. Nancy, INFA.
8. Leplat. Article in: *Bulletin d'études et recherches pédagogiques*. January-March 1963. Paris, CERP.
9. ibid.
10. Mechner, F. *Programming for automated instruction*. New York, Basic Systems Inc., 1961.
11. Greco, P. Notes sur la coopération des psychologues et des enseignants dans le cadre des expériences didactiques. *Revue de l'APEM*, 1969, p. 27-32.
12. ibid., p. 29.
13. Unesco. Meeting of experts on teaching and learning methods in university institutions. (Unesco, Paris, 23-27 September 1968). *Final Report* (ED/CS/132/4. Unesco-IAU/TLM/5).
14. Leplat. op. cit., p. 46.
15. ibid., p. 146.
16. Mechner, F. op. cit., p. 146.
17. Woodgate, Henry S. *Planning by network. Project planning and control using network techniques*. 2nd ed. New York, Brandon/Systems Press, 1967.
18. Chomsky, Noam. A review of B. F. Skinner's *Verbal behavior*. *Language*, vol. 35, no. 1, 1959, p. 26-58.
19. ——. *Cartesian linguistics*. New York, Harper & Row, 1966. 119 p.
20. Antunes, A.; Lanoux, J. *Étude de population et enseignement programmé*, p. 88-96. Paris, Progrès International, 1967.
21. Colloque sur les modèles et la formalisation du comportement. Paris, 5-10 juillet 1965. *Actes*, p. 216. Paris, Centre National de Recherche Scientifique (CNRS), 1967.
22. ibid.
23. ibid.
24. Greco, P.; Kirchberger, A. *Rapport de mission CDEP*. Paris, Centre de Documentation sur l'Enseignement Programmé, IPN, 1965.
25. Landa, N. L. *Diagnostic et enseignement programmé*. Paris, Centre de Documentation sur l'Enseignement Programmé (CDEP), 1967. French translation of paper presented in Düsseldorf.
26. Talysina, B. F. *Principes théoriques de l'enseignement programmé*. Chapter IV. (French translation of a course given at the Polytechnical Museum of Moscow; in preparation.)
27. Richelle, Marc. *Le conditionnement opérant. Une introduction et un guide à la recherche du laboratoire*. Neuchâtel-Paris, Delachaux et Niestlé, 1966. 223 p. (Collection actualités pédagogiques et psychologiques.)
28. Trakhenbrot. *Théorie des algorithmes*, p. 5, 9. Paris, Éditions Dunod.
29. Namian. Document d'accompagnement du cours télévisé d'informatique. *Télé-CNAM*, (Paris), 1re partie, 1968-69, p. 16.
30. Landa, L. N. op. cit.

31. LANDA, L. N. Recherche sur l'application de la logique mathématique et de la théorie de l'information à quelques problèmes d'enseignement. (Article not translated.)

CHAPTER IV

PROGRAMMED INSTRUCTION IN CLASS AND SCHOOL

We have examined some programming techniques and considered their shortcomings. With the sequences ready, evaluated, and validated, the time has come to use them in the class-room. There are other problems to be solved which require another type of programming, since their elements no longer relate solely to the field of programmed instruction, namely the large-scale use of tested sequences.

At this point we meet the problems which arise when a formalized educational system is made to absorb a technology which is bound to disrupt it. It is true that programmed instruction cannot be used in schools without the organization of work, time-tables and methods being affected. While the theories and techniques of programmed instruction are an inestimable asset in teacher training, the benefits of this technology in the class-room are as yet untapped. Having recognized that it can be used as a means for training teachers, the latter must be shown how their pupils in turn can benefit.

Programmed instruction is a boon to teachers, and the extent to which it can help in their training has been indicated. How can pupils make use of this technology? As already emphasized, syllabuses, methods, time-tables have all been turned upside-down for the sake of a single sequence. If we wish to generalize the use of programmed instruction, whether for a single subject or for several, we must ask ourselves what will be the likely implications.

The introduction of programmed courses into an established educational framework raises questions which must not be neglected. It is because their importance has been disregarded that many experiments have been short-lived and that many others have been unable to extend beyond a few experimental classes. If a large-scale use of programmed instruction is envisaged —and only then does it become economic—thought should be given in advance to the type of organization and the means necessary to launch the operation.

The organization involves syllabuses, and also methods, allocation of work, etc. The means are obviously the devices or aids, but they also include the teams of programmers, and the training to be given to them and to the teachers concerned, and so on. All this must be considered when it is decided to use programmed courses in the class-room.

THE ORGANIZATION OF TEACHING

It has been emphasized on several occasions that the use of programming techniques tends to induce or to renew criticism of the syllabuses, i.e. of the curriculum, to such an extent that it may be appropriate to use programming with this end in view. However, this does not necessarily mean that discussions lead to constructive ideas; we have pointed out the dangers, the digressions, the tendency to be satisfied with purely general criticism.

Discipline is needed, and since we cannot provide any method for this, we have put forward hints, advice or recommendations which experience has shown will make it easier to tackle the problems concerned. To the extent that this is achieved, the practice of programming is a valuable training outside its immediate field. But it is not for the purpose of seizing upon any argument in favour of such training that we suggest using programmed instruction to clarify teaching problems. If the practical application of programmed instruction is really desired, this property becomes a determining factor.

THE CURRICULUM

The curriculum need not be turned upside-down if only one or two sequences are used. They can perfectly well be introduced into a course without giving rise to any desire for reform. If, on the other hand, programmed instruction is to be used systematically, then syllabuses may need to be revised. Before discussing this, certain comments seem called for.

In countries in which syllabuses are drawn up at a national level (e.g. in France), the trial introduction of programmed instruction has frequently only involved a few lessons, or a few experimental sequences. To turn these to best account, the theme has been chosen from the syllabuses in relation to its difficulty. Its scope, its content and even its use have been so planned that the programmed course will fit into the normal syllabus without disrupting it in any way. In other words, the conception and the use of programmed instruction has been made subject to the framework, the demands and the norms of traditional teaching. This timidity of approach in what are mere experiments has frequently hindered discussion of the real problems raised by large-scale introduction.

It would, in our opinion, be of little use to train teachers in this new technology without also advising them of the very real problems they will meet in putting it into practice.

For purposes of experiment we can always manage with the existing frameworks and structures; but if we want to go further than this, how are we to conceive a generalized use of the technology of programmed instruction?

Let us suppose we wish to 'programme' mathematics teaching for children aged from 11 to 12 years. The whole course must be planned because the scope of what is involved in programming excludes in practical terms any preparation as one goes along. The various stages must therefore be decided in detail well before the sequences are introduced into the class-room. A choice of approach will also have been made, as between 'new' and traditional mathematics, or as between normative, functional and descriptive grammar and so on.

No one can fail to realize that these choices are vital and that they must be made in relation to educational aims which no teaching technology is qualified to define. Conversely, recourse to any teaching technology implies that these choices have been made. These decisions no longer come within the exclusive province of teachers, teacher-educators, or research workers: they are a matter of policy in which the education authorities play a decisive and possibly unaccustomed role. Although their responsibilities may demand a great sense of what is practicable and the ability to innovate (without destroying) long-established educational structures, they are here faced with the need to make a clean sweep. And to do things by halves and innovate in small doses, is to court disaster. There seems then little further need to stress the significance of any plan for renewing teaching methods which involves programmed instruction.

Curriculum reform and a decision on approach and aims are necessary before programming can be coherently planned. Yet programming also plays a part in arriving at these decisions. To a certain degree we are in a vicious circle. But it reflects the fact that these techniques must be tried out (this is as true for programmed instruction as it is for audio-visual aids) to discover the best ways of using them. This practical experience often helps to provide more precise definitions of aims which had previously been expressed in abstractions and generalizations. Once this has been done, it is possible to decide if these means are suitable for achieving these aims. Such a remark may be unoriginal but we cannot really accept the endless repetition of unoriginal experiments, in which programmed instruction is set aims for which it was never intended, simply because other means have been found or because its potential was unknown.

Another question which keeps recurring is whether or not everything must be 'programmed'. In other words, are all aspects of all subjects to be included? The question always arises immediately programmed instruction is encountered. Replies are generally as varied as they are evasive; all betray embarrassment. But those who put the question have different considerations at the back of their minds from those who find difficulty in replying to it. The former, faced with the prospect of renewal of their teaching methods, are thinking of the whole artistic sector, which in their opinion, defies explanation ('How can appreciation of a Shakespeare sonnet be programmed?'); the latter are reflecting on the shortcomings of programming techniques.

Yet there have been several large-scale experiments in which the teaching of a whole subject has been boldly entrusted to programmed courses alone, the teachers confining themselves to distributing and collecting them.

To teach a subject by using a programmed course alone is obviously utter nonsense. No doubt it is a means of 'economizing' on teachers and of meeting grave shortages. But to imagine that this provides good teaching is untenable. One has only to reflect upon what is involved in learning any subject to realize that it is quite impossible to standardize it. By temporarily meeting the teacher shortage in this way, we are not really preparing to meet future requirements. Rather than regenerating teaching, we are in danger of systematically imposing particular teaching traditions on a large scale. In developing countries, where progress is in part conditional on intellectual investment, it would be wrong to consider using educational technology in this way, though in the short term this solution may appear attractive since it provides tuition for students at a time when teachers are in short supply. Another point that should be borne in mind is that when this solution is chosen, the material used in the programmed courses is almost inevitably the most traditional!

So one should not try to programme everything. The question then arises of how to choose what can be programmed and how to teach what cannot. Certainly it is as easy to refute the first solution as it is hard to find another solution which can be justified by proven criteria. The theories and techniques of programming are not sufficiently advanced to take into account the specific characteristics of the different subjects to be taught or what is involved in learning their particular concepts. In the absence of any clearly defined methodology for each subject it is inadvisable to prescribe a single method based on current all-purpose techniques. Caution alone can dictate the choice of subjects or units to be programmed. In general, subjects which can be well structured and which require mechanical or repetitive activity seem initially to be the most suitable for programming. As a means of distinguishing them, these criteria leave a good deal to be desired. However, there are no others: in other words, syllabuses must be closely studied before it is possible to define which parts will be programmed.

One last important remark is called for. Once a decision has been taken as to which parts of the syllabus (or syllabuses) are to be programmed and these have been organized, they will have to be inserted in a course, other parts of which will be taught by other methods and other means. The problem that then arises is of making the different parts follow on to and relate to one another; this necessitates over-all 'programming', in which the programmed lessons are seen as stages in the course as a whole. This programming is precisely the 'organization of teaching' mentioned previously; it sets up requirements and restrictions the nature of which depends on the amount of programmed instruction included.

The first requirement concerns the syllabuses.

Content of the syllabus

It is first necessary to decide which subjects are to be programmed. The choice should preferably be made by the best specialists in the subjects who are already acquainted with the practice of programmed instruction. A short course on the theory and practice should provide them with sufficient knowledge to guide their choice. The choice is a vital matter when large numbers are to study the programmed courses.

The next step is to determine precisely the approach to each of the subjects chosen, i.e. the general outline of the syllabus, the methodology and the aims in mind ('traditional' as against 'modern' mathematics, for example). The choice cannot be made without obtaining the opinion and the agreement of the educational authorities. This is only seemingly restrictive, obliging as it does those responsible for the choice to look beyond their own limited field of experience, and consider the repercussions on a much larger number of students.

The introduction of programmed instruction does not necessarily bring with it a complete reform of school syllabuses. On the one hand, it is possible to visualize a new technology solving the problems of supply and demand without in any way altering the syllabuses or the methods. Experience confirms that this can be achieved, although it also shows that this type of teaching is often more costly than recourse to traditional methods! On the other hand, some effect on syllabuses is inevitable if one wants to make full use of the resources of this technology. To talk in terms of completely reshaping syllabuses would in fact be an exaggeration; in any case it would be impossible to achieve straight off. But the progressive introduction of technology certainly demands more rigorous planning.

What one must therefore be able to do is put forward a plan for 'developing the use of new educational techniques'. Syllabuses are but one of many elements in such a plan. And if the course is designed for pupils 9 to 11 years old (*cours moyen*), due consideration must obviously be given to the course they will follow the next year and which must be a continuation of what they have learnt. The syllabus must therefore include the programmed course in such a way as to avoid causing a break in a continuing educational process.

Apart from determining the approach, the preparatory work includes working out a plan which lays down the content and progression of what is to be taught. It may be feared that in desiring to plan the successive stages of teaching in this way one is being very rigid and imposing a constricting framework. Yet if this is not done, the opposite fault occurs: questions which have not been considered beforehand are met in mid-stream, and one is always tempted to go right back to the beginning. But even if one is no longer satisfied with these programmed courses, one still has them and has got to use them; the resulting malaise is not conducive to continuance of the work. For this reason, prior studies and decisions relating to the syllabuses deserve most careful consideration.

This has been attempted in the Unesco project for the development of programmed instruction in four French-speaking countries of Central Africa. Documents summarizing this preparatory work will accompany the sequences which teachers are to use with their classes [1].

A first list of sequences can then be established. This consists in:

(a) isolating those parts of the syllabus to be programmed; (b) deciding the approximate number of sequences required for each. But this task is already to a large extent in the province of the team of programmers rather than that of educational specialists or administrators.

Once this has been done, the team of programmers is able to get down to work, prepare the necessary sequences for each subject and try them out. But this will give rise to some very tricky problems in relation to the methods to be used.

CLASS-ROOM METHODS

The term 'method' is ambiguous in itself: it may mean directions for use, the alternation of programmed and unprogrammed lessons, new time-table arrangements for students and teachers, different types of activities or the atmosphere in which these activities take place, etc. All these elements are more or less closely involved. They will be discussed in an arbitrary order, that of the effects, in the full knowledge that the respective priorities are open to question. But that is not important since, once all the effects are manifest, the various elements fall into their own order of priority depending on criteria or factors which cannot always be foreseen.

Primary effects

These effects derive mainly from two characteristics: the programmed course does not cover all the teaching of a subject; and the students do not all progress at the same speed.

The programmed course consists of sequences spread at intervals over a whole year's teaching of a subject. Programmed lessons alternate with other lessons for the students (Fig. 31).

The programmed and unprogrammed lessons must be so co-ordinated as to ensure continuity in the learning process. The programmed sequence has already been explained.

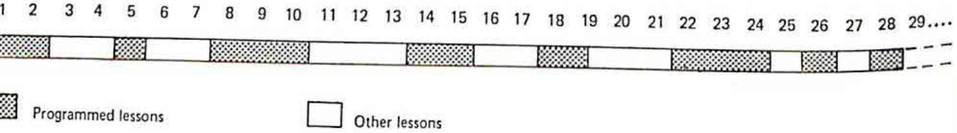


FIG. 31. Lessons.

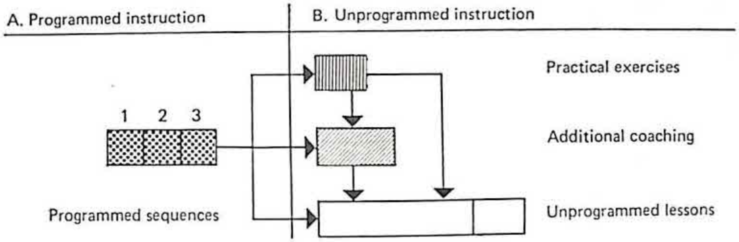


FIG. 32.

As for the other lessons, they may serve several purposes: (a) to apply in practice what has been learnt; (b) to help students who are experiencing difficulty; (c) to cover parts of the syllabus which it was considered could not be programmed (Fig. 32).

In fact, the intervals between programmed lessons would be suitable for all these purposes. Only certain students need additional coaching; the others can get on to the following unprogrammed lesson.

It will be seen that working with programmed lessons means that each student or each group of students is treated differently before going on to the following lesson. This being so, the process of splitting up the class goes on beyond the sequence which is being studied, and it is important to decide in advance how far one feels able to go in this respect. It is difficult to give each individual student the exercises or extra coaching he needs, so one is led to establish groups to prevent teachers and programmers being burdened with too many separate tasks. This entails laying down a procedure and criteria for establishing groups, after tests have been given at predetermined intervals.

A very simple example is provided on the next two pages, which shows the distribution of programmed lessons for four subjects in the Central African project: the blank spaces denote either practical exercises, supplementary coaching or new lessons. A more detailed plan would obviously have to specify the action taken by the teacher in each case and be accompanied by documents explaining its nature and purpose. In this connexion questionnaires and final tests take on a very important role! The table would, of course, then be much more complicated, and another difficulty would become apparent: that of the relation between the teaching of different subjects.

The figure shows the apportionment of programmed lessons for four subjects week by week. But in the course of one and the same week, re-apportionment is necessary since it is unthinkable that the same students should in succession study a sequence of

	MATHEMATICS			GRAMMAR			NATURAL SCIENCE			GEOGRAPHY		
	Programmed lessons	Final test	Unprogrammed lessons	Programmed lessons	Final test	Unprogrammed lessons	Programmed lessons	Final test	Unprogrammed lessons	Programmed lessons	Final test	Unprogrammed lessons
1	Seq. 1- Sets theory	1		Seq. 1 Subject: Introduction					Introduction to drawing (1 hour)			Practice in manipulating the globe: shape, dimensions, orientation
	Seq. 2- Sets theory	2										
			Exercises on Seq. 1 + Seq. 2	Seq. 2- Introduction (Contd.)	1, 2				Introduction to drawing (1 hour) (cont.)			
2	Seq. 3- Definition of a set	3		Seq. 3- Subject: Place number	3		Seq. 1- General structure	1		Seq. 1- The earth: shape, dimensions, orientation	1	
			Exercises on Seq. 3	Seq. 4 - Subject- noun, pronoun, substitute, adjective, infinitive	4				Diagrams in exercise book			
			Exercises (cont.)									
3	Seq. 4- Inclusion	4		Seq. 5- Subject: Groups of words	5				1st and 2nd hours - Bones of human head and trunk	Seq. 2 - Longitude and Latitude	2	
			Exercises on Seq. 4									
	Seq. 5 - Intersection	5				Lesson on subject: noun, pronoun						
4			Exercises on Seq. 4 and 5			Lessons on subject: agreement of the verb (2 lessons)			1st and 2nd hours - Human skeleton (cont.) Thoracic girdle upper limbs	Seq. 3 - The earth: its movements their geographical consequences	3	
	Seq. 6 - Junction	6										
			Exercises on Seq. 4, 5 and 6									
5	Seq. 7 - Relations	7		Seq. 6 - Comparison Introduction	6				1st and 2nd hours - Human skeleton (cont.) Pelvic girdle, lower limbs	Seq. 4 - The earth: its movements, their geographical consequences (Cont)	4	
			Exercises on Seq. 7	Seq. 7 - Introduction (Contd.)	7							
	Seq. 8 - Natural integers	8										
				Seq. 8 - Degrees of comparison	8				1st and 2nd hours. Joints muscles and movements			Revision Seq. 1-4. Presentation of documents (exercises)

16			Exercises on Seq. 13-14	Seq. 16. Chronology (Introduction)	16							
	Seq. 15. Distribution of + in relation to ×											
17			Exercises on Seq. 15	Seq. 17. Chronology–Anteriority	17				1st and 2nd hours–study of a tilapia			Practical work on relief.
			Continuation of course according to indications of the mathematics programme	Seq. 18. Chronology–Posteriority	18							
18											12	
19						4 lessons on chronology – the tense of verbs (past, present and future)	Seq. 9 Vertebrates	9		Seq. 12. Sea waters	13	
							Seq. 10 Vertebrates (contd)	10				
20						– Agreement – conjunctions and tense – adverbs and tense	Seq. 11. The peanut: vegetative structure	11		Seq. 13. The coasts	Study of documents (photos, maps, etc.) relating to coasts	
									Diagrams in exercise book			
21						The rest of the grammar course is not programmed. It must be devoted to: – conjugation – agreement . . .	Seq. 12. The peanut, life of the plant	12				
									Diagrams in exercise book		The rest of the geography course (man and natural environment) is not programmed.	
22						From the 20th week onwards the time-table will devote 1 hour per week again ~~to [illegible]~~	Seq. 13. The peanut seed and germination	13				
									Diagrams in exercise book			
							Seq. 14 The coral tree	14				

mathematics, one of geography, one of grammar. The weekly time-table must be worked out taking into account the effort expected from the students. The ideal would of course be to present them with a sort of self-service arrangement. That stage has not yet been reached for all sorts of reasons. It is still indispensable to plan the teaching of all subjects as a whole: this is the basis of what is called 'multidisciplinary' teaching. For the time-table this involves allocating the time spent on programmed lessons and on other lessons. Some will say that this task devolves on the administration since, in post-primary education, it is responsible for drawing up the teachers' time-tables. In the primary schools this often falls on the teacher alone. In both situations, although they are very different in relation to the pupils, programmed lessons must be planned and allocated in a similar over-all way for all teachers or on a basis to be worked out together. The reason for this has already been mentioned: it is at present impossible to think of using programmed instruction in a way which will satisfy the individual requirements of each teacher and yet be efficient. However unfortunate this may seem to a teacher-educator, the facts cannot be ignored.

Thus the number of pupils concerned must be known, and the teachers responsible must plan their work relatively rigidly. Teachers, therefore, will find themselves obliged to carry out tasks which they have not defined themselves. This will change little in the normal run of things except that they will be asked to keep to a time-table which they have shared in drawing up. No one will be surprised to know that this gives rise to controversy. It should merely be noted that the more individualized teaching becomes, the greater the inflexibility required in organizing teachers' work. No doubt this is merely a temporary phenomenon, but it is certainly trying. However, it paves the way for passing to the next stage, and, in any case, no other way. By 'passing to the next stage', we mean that pupils who are better taught take a burden off their teachers, leaving them greater opportunities for seeing to individual needs.

This aspect must not be under-estimated in preparing the launching of programmed instruction on a large scale. It is well known that it is pointless to try and impose a technology or new methods on teachers; repeated failures are sufficient proof. The results would be as bad if they were obliged to follow a detailed weekly schedule to the letter, without any explanation of the reasons, the aims and other determining considerations. If it is hoped to use programmed instruction and such problems are brought to light it is pointless to think in terms of half-measures.

When considering the possible uses of programmed instruction in relation to other teaching methods, a question arises which is the source of much controversy and leads to many misunderstandings. This is the problem of the relationship between audio-visual aids and programmed instruction. Whether they are taken as a single field or seen as two separate fields, there are frequently heated discussions based on semantic disagreements. Those in favour of holding them apart claim that programmed instruction 'individualizes' what is to be taught, whereas AV (audio-visual aids) provide 'mass' dissemination. Those in favour of wedding them emphasize that the one depends on the other, AV on programmed instruction or programmed instruction on AV, as the case may be. Those who support programmed instruction maintain that educational technology calls for a general programming technique of which it alone offers models; those who support audio-visual aids observe that all the means used by programmed instruction derive from AV, so that programming contributes only to organize the use of these means. To attempt to wed the two on this basis is liable to be as long and as tortuous a process as a law suit in the Middle Ages [2].

At present it is hard to see what kind of hybrid their union might produce. In short, it is impossible to choose between the suggested answers for want of a working definition of educational technology. However, it is possible to clarify certain ambiguities and to avoid certain misunderstandings.

The misunderstandings are due to several causes which stem especially from the teaching functions ascribed to audio-visual aids and which it would serve no purpose to consider here. Should the need arise, teacher-educators can readily invoke common-sense principles in regard to the two techniques, which are still separate as far as terminology is concerned.

Programmed instruction has certain characteristics of its own: individual learning, the automation of learning, and built-in testing. These three characteristics are specific to programmed instruction in the sense that they guide programmers at all stages of their work. They do not come into play in compiling audio-visual material. On the other hand it is obvious that many audio-visual aids can be incorporated into a programmed course: slides, film-strips, tape-recordings, video-tape, etc. Others, on the contrary, such as radio, television or sometimes film, do not display the characteristics mentioned. There is certainly automation but it ceases to be the basis for adapting to the pace of the individual students. And although testings may occur it is not an integral part of the learning process.

There are, therefore, real differences and it is sometimes imagined that there is a division of functions: programmed instruction supplying individual learning and audio-visual aids, collective learning. If it is envisaged using them together, their use must be 'programmed' and it is programmed instruction which furnishes the models for this purpose. Various models are possible depending on the role to be filled by programmed instruction and AV respectively. Let us mention some of these roles and in each case show how they are normally filled.

→ Classroom teaching → (AV)
→ Individual teaching → (PI)
→ Illustration after the lesson → (AV and to a lesser extent PI)
→ Additional coaching before or after the lesson → (PI, AV)
→ Teaching 'at a distance' (*longa manu*) → (PI, AV)
→ Testing learning → (PI)
→ Built-in testing → (PI)
→ Simulated situations → (PI, AV)
→ Simulated dialogues → (PI + AV)
etc.

If we want to combine various functions in the teaching of a given subject, it is possible to produce an elaborate plan which provides for the use of one or other means. On this basis any number of possibilities may be imagined. But the combination of two sorts of technologies necessarily entails programming their use, whatever the type of combination chosen. The introduction of programmed instruction brings to light still further requirements and in particular the need for continual testing. If, for example, a televised lesson is to be used, it is vital to be certain that the pupils have the necessary background to follow it, and afterwards those who have got left behind will have to be allowed to catch up before going on to a programmed sequence or a new collective lesson.

Comments. Teachers may wonder why a combination of technologies rather than their complete integration is suggested. It might be thought desirable, for example, to produce a programmed television broadcast, or carry out the collective study of a learning sequence. There is nothing against such experiments, but the 'integration' achieved will be in name only. For if the content and the pace of the learning cease to be that of the individual student, we are no longer dealing with programmed instruction. But although the label may be wrong, is it not possible to suppose that such attempts might produce something positive? It is difficult to answer such a question decisively. There have been experiments which have not produced very convincing results. To provide sufficient time for the slowest students to answer, the speed of a television broadcast must be reduced and silences and interruptions must occur. By trying to make allowances for the individual student's rate of progress the unity of the broadcast and its own intrinsic rhythm is destroyed.

We have spoken of combining means without giving any example or model. The omission is deliberate and inevitable. The number of models is legion, but, as we have seen, their principles are very simple: it is easy to imagine a general plan combining different techniques worked out according to the teaching aims of a given project. In detail, everything depends on the factors taken into account, and these and the relevant criteria vary from situation to situation. A model, even if it is presented as an illustration, tends to be regarded as a pattern or exempler by those to whom it is shown. On the other hand, the elaboration of a model adapted to local needs can be an excellent exercise in group thought. As in the production of a sequence, the different tasks must be separated. The general outline and then the detailed plan are worked out with total disregard for materials, costs, etc. These will only be considered once all the requirements have been defined.

Specialists in audio-visual technology recognize that programming usefully disciplines their thoughts and ideas. There is no doubt that training in programmed instruction must be included in the training for other technologies. Thus, just as it is true that certain functions are specific, so it is also true that their combined use requires a uniform training with emphasis on a particular technology according to the desired field of specialization. But initially all budding specialists should undertake certain basic studies in common; this gives them sufficient understanding of the technologies in which they have not chosen to specialize to be able to communicate with one another and thus work out these models to which each will be able to contribute according to his skills. (Diagram 2.)

Once again it is in the sphere of training that the first benefits of programmed instruction are felt, even though what is being considered is its large-scale use in the class-room. This further serves to emphasize that to use programmed instruction without any training can in no circumstances be justified.

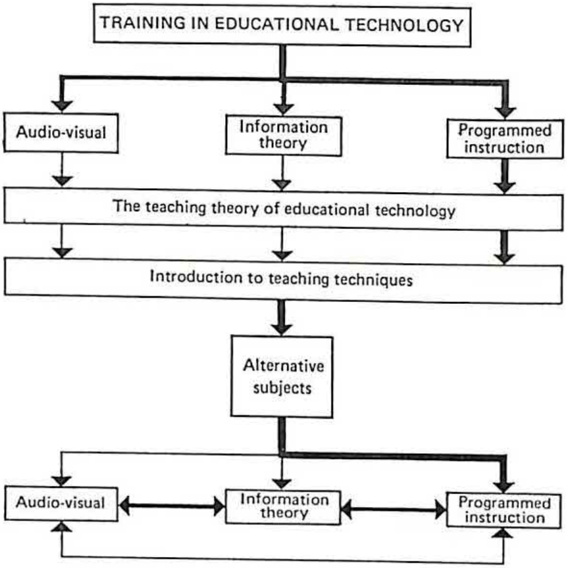


DIAGRAM 2.

Secondary effects

In our discussion of methods we have until now only mentioned the consequences brought about by the new approach to syllabuses and the form in which they are put for teaching purposes. There are, however, other results affecting the framework within which the teaching is provided: time-table, allocation of subjects, levels, etc. These stem from the primary effects and for this reason are called 'secondary'. In fact they give rise to so many difficulties that they often end up by actually determining in what form or circumstances a new technology is launched.

All these consequences stem from individualization. Since this is based on the rate of progress and not on the demands of the syllabus, it breaks down the normal framework in which students are taught. This is scarcely surprising! Neither the framework nor the teachers trained to provide individualized teaching are in fact made for that purpose, so that a link at a time, by a chain reaction which it is easy to trace, the framework is gradually weakened.

Time-tables. A class of thirty pupils is studying a programmed sequence. The first pupil was able to finish the sequence in half an hour whereas the last needed one hour five minutes. To make the whole class wait for the latter to finish before going on to the

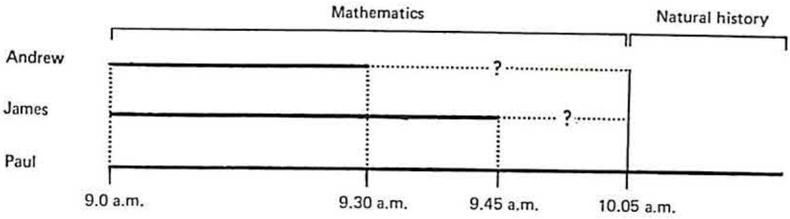


FIG. 33.

next lesson would, in fact, be feasible since each pupil would have been allowed to go at his own speed. But if from one lesson to the next the whole class must go at the speed of the slowest then the 'idle time' for those who are waiting is liable to be filled in a manner somewhat distracting to the rest.

A time-table composed of a series of one-hour periods is no longer suitable now that the pace of learning can be varied; such a time-table is, indeed, an obstacle to fast learners. The problem is therefore how to adapt the time-table to individual rates of progress.

Let us take, as an example, a first-year secondary class, including three boys called James, Andrew and Paul. They are studying mathematics, and they sit down to programmed lesson No. 4 on Monday at 9 a.m. Andrew finishes the lesson at 9.30 a.m., James at 9.45 a.m. and Paul at 10.05 a.m. (Fig. 33).

The mathematics lesson is followed by a natural-history lesson including practical work, which all pupils must attend. Must Andrew then wait 35 minutes in between, and James 20?

Something must be done to use the 'idle time'. There are several possible solutions: Andrew and James can fill in by going on with the study of mathematics; they could be given the chance to use the extra time they have gained from their progress in mathematics in order to catch up in their weaker subjects, geography or grammar, for instance; or they could be left to help their slower classmates. All these solutions are feasible; the only snag is that in practice any such system is difficult to arrange, owing to the vast number of possible permutations and combinations. This opens up the prospect of a school in which pupils apply the knowledge they have acquired in accordance with their needs, aptitudes or achievements. It is interesting to speculate how such an establishment would function in the absence of any restrictions and removed from any economic or social context; the 'systems' thus devised would have the advantage of being conceived before the pressure of requirements makes itself felt. The reforms which these latter necessitate (often belatedly) might well be modelled on such systems with the participation of the teaching profession.

Meantime we have the existing classes, in charge of the existing teachers. Pending the introduction of the ideal teaching system, which will use every means to enable each individual pupil to acquire by 'self-instruction' all the knowledge he needs, it is the teachers' job to devise an interim method which, though not yet going so far as enabling pupils to teach themselves, at least provides the maximum scope for individual adaptation.

The grammar hour will overlap the arithmetic or geography hour until, in the end, the division into one-hour periods is scrapped. Those who have worked in single-teacher schools attended by children whose ages range from 6 to 12 will know what this means, whereas single-subject teachers will not; it necessitates a great deal of team-work, allocation of tasks, and so on. The teachers of the various subjects will need to co-ordinate in order to decide on the syllabus offered to each individual pupil. The planning of the syllabus will depend on the pupil's results in tests. In the last resort, the method used for collecting and interpreting such data and applying the relevant conclusions to the subsequent stage, determines the basic character of the proposed teaching system. Programmed instruction may be said to be pluridisciplinary in regard to the elaboration of sequences, but multidisciplinary at the application stage.

Adapting the rate of progress to individual needs means that there may be times when the members of a class will be working on different things, others when they are all working together. Time-tables should be so arranged that pupils are able to split up into groups, or to pass on to another activity directly they have finished what they are doing. There should be a wide range of activities, arranged in such a way as to give variety. Care should be taken, for instance, not to give pupils a series of programmed sequences to study the whole morning without a break; they should be sandwiched between periods spent on other activities, of a different nature or requiring less concentration. All existing teaching methods can be brought into play: active methods, activities designed to arouse children's interest, observation lessons and so on.

As regards methods, therefore, individual needs are catered for by the introduction of diversity and variety. This involves close co-ordination of the work of the teachers, who are thus obliged to submit to a minutely organized system in order to provide a wide range of individual possibilities for their pupils. It might almost be said that the more freedom they give their pupils, the less they leave themselves.

CONCLUSIONS

The introduction of a technique such as that of programmed instruction—more particularly, a combination of several techniques—involves complex reorganization, raising even greater difficulty, perhaps, than the production of the programmed sequences. Yet the importance of this aspect of the problem is frequently underestimated, it being regarded rather as an administrative problem which is bound to come right in the end. But this is in fact not so, and programmed instruction projects may quickly collapse or fail to bring about any change of attitude, unless allowances are made for the repercussions of this new system on the everyday life of the class.

The whole system is based on the methods used for testing that the material has been learnt, and on adapting further instruction to the results of such tests. Though an over-all, co-ordinated plan of work must be drawn up, there is no question of adhering blindly to it. On the contrary, the plan must make provision for recording and taking into account the results of the tests, in order to adapt the contents and methods of the subsequent stage to the pupils' needs.

Thus considerable preparatory work will be entailed: programming, training teachers, giving pupils the necessary background information. Many factors are involved, complicating the task. The result is that a programmed instruction project is always something of an adventure; and, this being so, it is obviously expedient to plan it in stages. Before applying the system on a general scale, it must pass through experimental and initial stages. This was the procedure adopted for the Unesco project launched in 1967 in four French-speaking countries of Central Africa [3].

No discussion of programmed instruction would be complete which left aside all these problems. It is worth while paying special attention to them, for the need for collective organization and regular co-ordination makes it imperative to abandon wait-and-see attitudes and the habit of muddling through. If future teachers were brought to realize this fact, when drawing up a detailed plan as part of their practical work syllabus, the training value of programmed instruction would be further vindicated,

Apart from the organization of teaching, however, there is also the problem of material organization.

MATERIAL ORGANIZATION

Whether programmed instruction is to be used alone or in combination with other auxiliary teaching methods, the production of teaching materials presupposes a complex infrastructure: there is not only the production of the actual teaching aids and the 'teaching machines', but also the organization of training courses to teach people how to use them.

AIDS AND DEVICES

Programmed sequences must be presented to pupils in some form. A whole series of aids already exists, ranging from the simplest to the most highly complex, so numerous and varied as to make description and classification difficult. The choice of aids depends on a number of factors: cost, functions to be fulfilled, maintenance. But it is not yet possible to determine what type of aids or devices might be economic and advantageous in function of one's budget and one's needs.

So far, the simplest aids are still programmed books and workbooks, which have the advantage of fulfilling all the functions demanded of programmed instruction without requiring any maintenance. In addition, they are easy to handle and would appear to be cheap to produce. In point of fact, the position needs to be examined more closely.

During the early stages of the Central African project, the work-book provided an adequate solution. But the limitations of this technique soon became apparent. During the 1969/70 school year, the plan was for each of 500 pupils in the first grade of general secondary schools to study approximately seventy programmed lessons. This involved the production of about 1,000 stencils, totalling 400,000 sheets of paper (weighing over a ton!) And the whole process of typing and rolling off the stencils—to say nothing of page-numbering, trimming and stapling—would have to be repeated every year. If the number of pupils rose, in these conditions, to several thousand, we can just imagine the cost of all these operations, to be repeated every year, and the weight of the resulting production.

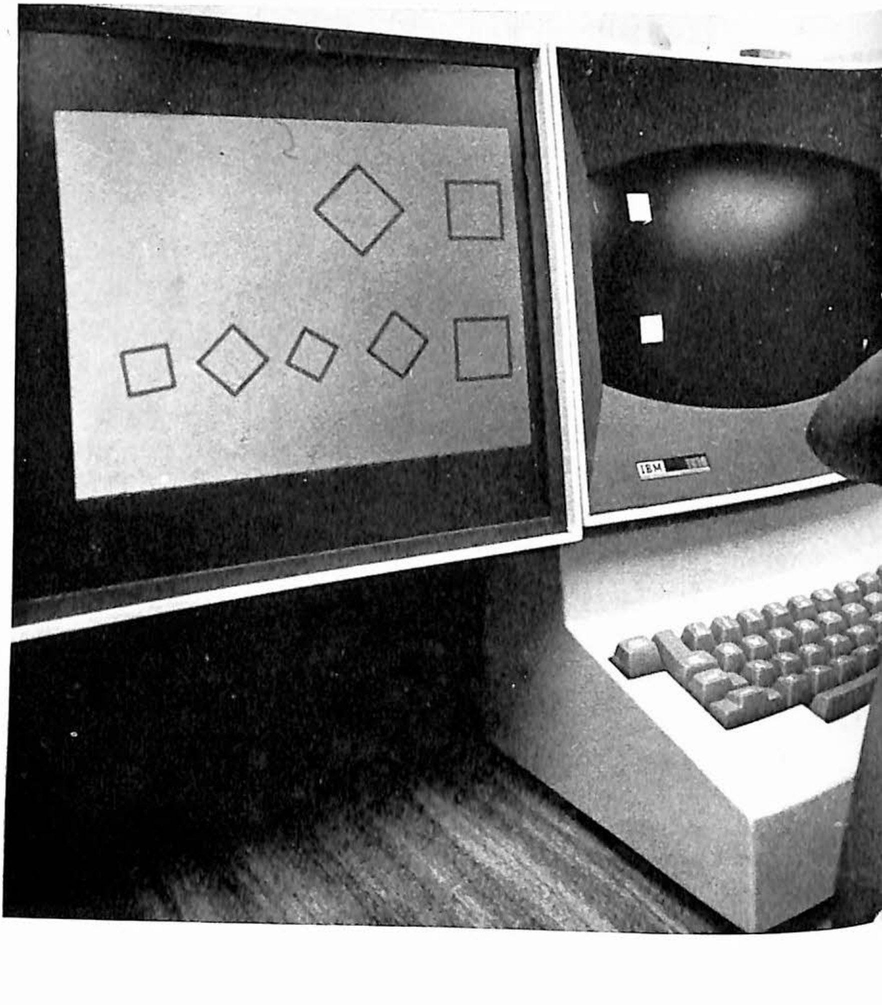
The solution to this problem is to present the sequences in such a form that they can be used again. The simplest way would obviously be to get pupils to write their answers on separate sheets of paper.

But a great number of mistakes are made and this system would make it more complicated to assess the results, besides

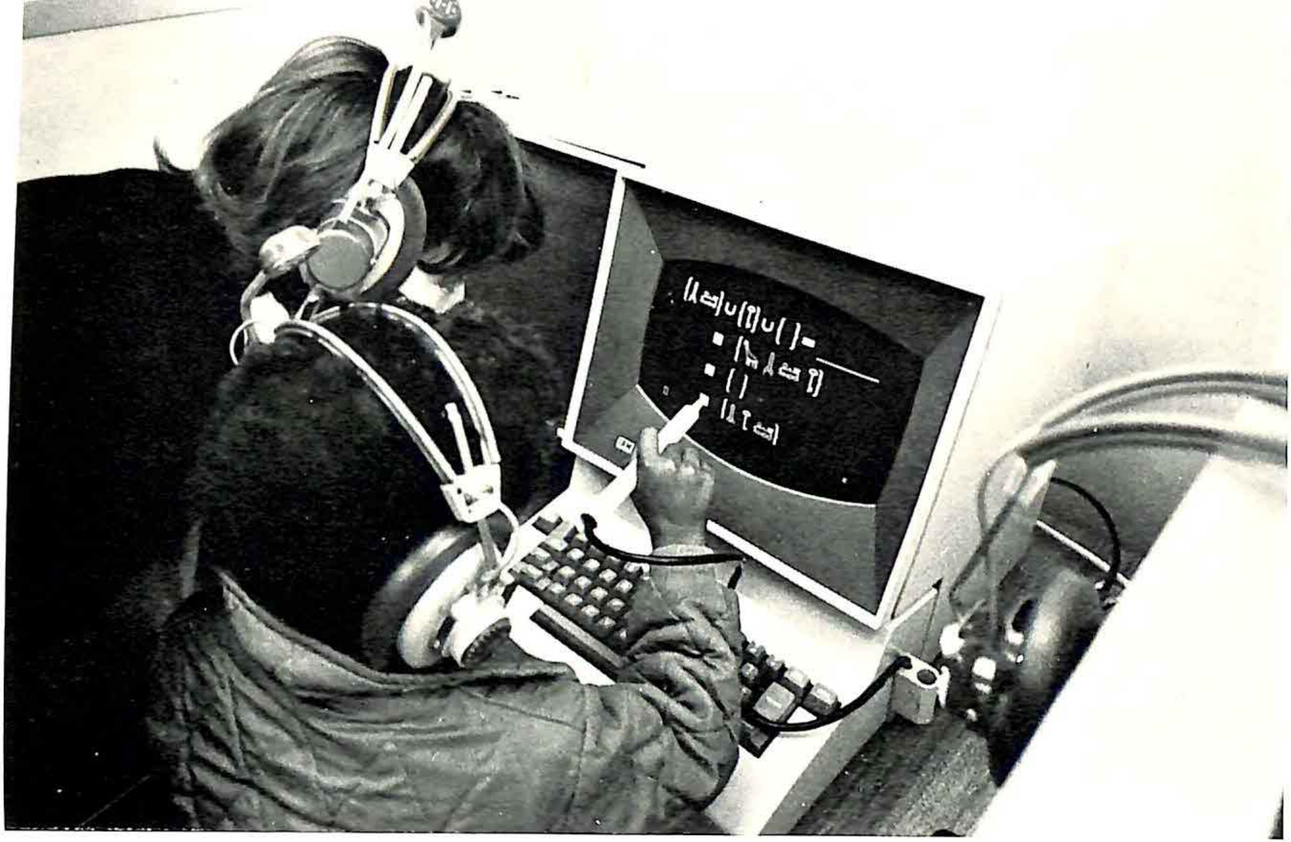
```
CORRECT!
        THE ADVERB IN THIS SENTENCE IS CLEVERLY.

TYPE THE LETTER OF THE CORRECT ANSWER.
HOW MANY TRIANGLES ARE IN THE BOX?
          A:  ONE
          B:  TWO
          C:  THREE
```

The teacher is a computer. On a typewriter-like terminal, a student answers questions generated on a screen by a computer. If his answer is correct, the computer will project a more difficult question. If the answer is wrong, the screen will display study material to tutor the student. Watching here is Professor Patrick Suppes of Stanford University in California, curriculum adviser for computer-based instructions. [*Photo: USIS.*]


IBM

Children's responses often are unexpected. This girl delights in covering her eyes to let the machine surprise her with the next problem. [*Photo: USIS.*]



A boy adds up the symbols for a rocket, locomotive and key with zero on top line of screen, touches one of three possible answers with a cathode-ray light-pencil. 'That's right', he hears on his earphones. [*Photo: USIS.*]

making an unwarranted additional call on the pupils' attention. Research is at present being carried out on the possibility of using work-books made of special materials, such that pupils' responses can easily be erased. In this case, the same sequences could be used several times, and it would no longer be neccessary to provide a separate work-book for each pupil. A set of sequences would be issued not to a certain group, but to a whole class; and it would be possible to envisage libraries containing sets of sequences, constantly available for use (thirty copies of one sequence would weigh less than two kilograms). There are grounds for hoping that some solution of this kind will soon be found. Technically, it presents no major problems. As regards cost, it appears to be a good deal cheaper than the mimeograph method (the cost would be less than one-fifth).

However, a certain initial outlay on staff, equipment and material is unavoidable. The actual production should preferably be concentrated in one place, or in a few places only. This involves setting up a system for distribution of the sequences to outlying schools, which again means careful organization. Because we have neglected these so-called minor considerations, expecting programmed instruction in itself to produce miraculous solutions, we have very often failed to take advantage of the facilities it offers. It is essential to combat the idea that the introduction of a new technique consists primarily in bringing about a change in attitudes and methods. Those who take this view wait to see the results before granting the requisite resources. And they will always prove right, since there can be no results; such results as there are must inevitably be scant and unconvincing until such time as all the material conditions needed for success are fulfilled. Yet we know very well that no technological innovations can regenerate education, either qualitatively or quantitatively, unless the requisite resources are made available from the outset.

We have made it amply clear that the success of the new method depends on the care taken to ensure the best possible conditions *before* embarking on it. We must apologize for labouring this point, which is a truism, but which people appear to have difficulty accepting: if there is to be programming in the two senses we have described, all decisions relating to the form of the programme and the means to be used for implementing it must be taken in advance.

There are of course available teaching aids and devices other than books or work-books; the cost of purchasing them in sufficient bulk for large-scale use will depend on the terms that can be obtained from the manufacturers. But this brings us into the business sphere where, as we know, each new deal has to be negotiated separately. Tenders will have to be invited for the supply of each specific item of material, whereas books and workbooks can be obtained without direct recourse to the manufacturers.

The obvious drawback of using simple aids is that the quantity of material that has to be checked assumes considerable proportions, so that hand-processing takes too long for the objectives to be adjusted sufficiently quickly. Yet the aim is, precisely, to eliminate this delay, this time-lag between the moment when results are checked and the moment when the appropriate adjustments are made. It is at this point that the machine for rapid information processing, the computer, comes into its own; indeed, for any large-scale project on the technology of teaching it is a *sine qua non*. At the same time, the computer is an all-purpose machine capable of fulfilling a variety of functions and it can be used, in teaching, for so many different purposes that any attempt to describe them all would fill a book in itself. Suffice it to say that the use of the computer in teaching raises the same difficulties as those raised by the use of programmed instruction as such. And in the training which it necessitates, the requirements and the obstacles are the same as those to which we have already referred. It is for this reason that we are convinced that teachers versed in the use of one technique only cannot be said to be fully trained: they need to be trained in the use of all techniques, even though in practice they may only have to use one.

PREPARATION FOR TEAM-WORK

We know already what programming involves in regard to the formation of teams and the organization of their activities; and there is no point in reverting to this subject again. Nevertheless, the preparatory activities entailed may seem daunting when it is proposed, in the face of the urgent need to give teachers time off in order to train in the use of these new methods, or to divert for the purpose material resources which have already been fully committed.

Preliminary courses for groups of about thirty teachers can easily be organized by two or three teacher-educators. Such courses can be incorporated in the training programme for student-teachers at teacher training colleges. The basic theories and techniques can be learned in a matter of about ten days. Most teachers' difficulties stem not from this, but from insufficient mastery of their special subjects. The first qualification for would-be programmers must be a high degree of competence in their own subjects; and the persons chosen to form the first teams of programmers will be selected on this basis. They will then receive more thorough training in the new techniques, studying all the difficulties encountered, and covering every aspect of the work, from the production of the requisite aids right through to methods of utilization. Such training need take little more than a month or two.

On the other hand, production of the first experimental aids requires time, the formation of trial classes, and rational practical organization. The experiment carried out in Central Africa is an example of what is involved.[1] A number of teachers need to devote their time to these activities, working in regular contact with the authorities. Meantime, information on the new methods can be made available to the future users of the system, the rest of the school-age population and parents. All the resources of mass-communication media should be brought into action in order to prepare the ground for introduction of the new techniques: television and radio, surely, are the obvious channels to use for proclaiming the entry of technology into the class-room.

And so, after denouncing the publicity which surrounded programmed instruction in its early stages, we now find ourselves suggesting that teachers should organize a campaign to publicize their activities in this field! But in suggesting that they should take on new tasks and new responsibilities, we have no intention of turning teachers into salesmen, extolling the virtues of their goods. The proof of programmed instruction lies solely in what it does to improve the quality of education for the greatest possible number.

REFERENCES

1. UNESCO. Stage d'enseignement programmé, ENSAC, Brazzaville. *Rapport final*, p. 23-61. Paris, Unesco, 1969. (ED/WS/157.)
2. DIEUZEIDE, Henri. Les machines à enseigner. *L'éducation nationale* (Paris), nos. 24-25, September 1963.
3. UNESCO. op. cit. The second part of this report was published by the École Normale Supérieure d'Afrique Centrale, under the title *L'enseignement programmé; guide pour le professeur*. ENSAC, B.P. 237, Brazzaville, People's Republic of the Congo.

---

[1] This example is of course valid only for the specific local conditions in which the experiment was carried out.

CONCLUSIONS

Programmed instruction is based on a wide variety of theoretical studies and gives rise in practice—as evidenced by the diversity of the techniques used—to numerous variants. The prospects it offers are, at first glance, neither clear nor particularly exciting: there is a wide gap between the promises of rigorous exactitude held out by its proponents and the empiricism of the techniques adopted in practice. No attempt has been made to conceal the shortcomings and imperfections of the method; but it has also been pointed out that in many cases the criticisms directed at such shortcomings have served to stimulate the inventiveness of specialists in one field or another, or induced them to undertake further research. It may be, however, that these same specialists, in an effort to attain greater exactitude through the use of new procedures and highly sophisticated devices, divert attention from some of the points which programmed instruction has shown to be vital. There is, for instance, a growing tendency to give priority to 'teaching machines' and their technology, as though the teaching tasks to be entrusted to these machines had also to be determined and analysed through the medium of the machines. While there is legitimate ground for concern at these tendencies, this should not be taken as an argument against programmed instruction. It is in regard to programmed instruction that the problems of the 'technology of education' appear most vividly and also perhaps that their actual dimensions can best be appreciated. But this by no means implies that it is at the root of these problems.

It is here, in our opinion, that the main importance of programmed instruction lies: it helps teachers to clarify the problems confronting members of their profession in the present-day world. The critical reflections prompted by the work of programming for new experiments lead to a re-consideration, not merely of the methods, means or content of education but also of the aims.

It is thus apparent that, whilst programmed instruction serves to draw attention to the numerous points still remaining obscure, it is not responsible for this obscurity. The problems still outstanding are essentially prior to it or posterior. The former category comprises such problems as the definition of over-all aims, a decision on the means to be employed for teaching the various subjects and the study of learning techniques; the latter includes determination of the equipment needed for attaining the aims selected (teaching aids and devices), training teachers to use such equipment and the best policy for introducing and developing the new teaching techniques. Solution of these problems will necessitate the formation of interdisciplinary teams, as opposed to the pluridisciplinary work involved in instruction in class. Lastly, it will be expedient, in the interests of greater efficiency, to integrate the functions of all persons who, in whatever capacity, are concerned with the care of pupils: i.e. not only the actual teachers, but also directors of schools, inspectors, teacher-educators and the national planning authorities.

It may be argued that all this relates to the future. But here and now programmed instruction, as presented above, can offer a solution for certain very specific local problems on condition that it is required to meet only limited needs, not implying any change in the main lines of the educational policy. As soon as wider needs are involved, however, it is essential to have an over-all plan, defining the functions of everyone concerned—teachers, administrators, teacher-educators, instructors, psychologists and research workers—within a coherent system. The 'programming' of the operation of this system corresponds, though on a different plane, to the 'programming' of the actual process of instruction.

Let us pause for a moment to examine the above remarks, the burden of which will be familiar to any teacher desirous of change. They throw light on two extremely important ideas. The first of these recalls the results of G. Simondon's analyses of technical objects and their mode of existence [1]. Simondon demonstrates that a technical object 'materializes' to the extent that the functions it fulfils become increasingly interdependent. This is the kind of interdependence we should have in mind when devising a teaching 'system' which 'programmes' the attainment of its objectives through the utilization of technical auxiliaries in the form of machines. If the rational introduction of these techniques into education is visualized in this way, the training of teachers must clearly include some instruction in the use of the technical objects which will be part and parcel of the everyday world of pupils in the future.

The second important idea is in line with the reflections of Jean Piaget, who holds that teaching continues to be an art in so far as it draws on and uses the results of the sciences. The main problems encountered in teaching stem from these sciences, so that teaching cannot claim to be an autonomous science itself. But this does not mean that the art of teaching cannot be studied in accordance with the rules of scientific method [2]. It may be said that programmed instruction is designed precisely for the investigation of this field, mid-way between the problems described above as prior and posterior. If this is so, it is easy to understand both the importance research workers attach to it and the large number of studies carried out on and through it. To take an example suggested by Piaget himself, the definition of the 'technology of education', it was only after long discussions—and there may be more to come—that a means was found to distinguish in technology between what concerns the actual tools and considerations relating to their nature, functions and rational usage. We now know that tools may be simple objects—wooden sticks, pebbles, containers, imaginary machines—the manipulation of which is a stage in the formation of logical operations. The utilization of these tools likewise entails a technology involving their functional usage and their suitability for attaining the conceptualized goals initially aimed at. At a time when many countries are concerned, for instance, with the problem of initiating children into the modes of thinking peculiar to information science, we realize that the computer is not indispensable: use of an imaginary 'machine' designed on the basis of consideration of the functions it is intended to fulfil, can suffice to prepare children to feel perfectly at home, later on, in the computer world. It is surely to the technology required for this kind of training that the prospects opened up by the new programming techniques invite us.

REFERENCES

1. SIMONDON, G. *Du mode d'existence des objets techniques.* Paris, Editions Aubier-Montaigne, 1969. (Collection: Analyses et raisons.)
2. PIAGET, J. *Psychologie et pédagogie.* Paris, Denoel, 1969.

FURTHER READING

The following is a basic list of references in English essential for anyone intending subsequently to go on to more specialized documentation.

PROGRAMMED INSTRUCTION: GENERAL

Dodd, B.; Kay, H.; Sime, M. *Teaching machines and programmed instruction.* London, Penguin, 1968. 167 p.

A general introduction, with a slant to practical issues and technical education.

Glaser, R. *Teaching machines and programmed learning.* Vol. 2: *Data and directions.* Washington, National Education Association of the United States, Department of Audio-Visual Instruction, 1965.

Substantial collections of articles by leading workers in programmed instruction; many discussions of research. In general, Vol. 1 discusses basic principles, while Vol. 2 concentrates on specific issues which arose during the years separating the two volumes, and many of which are still open.

Glaser, R.; Lumsdaine, A. *Teaching machines and programmed learning.* Vol. 1: *A source book.* Washington, National Education Association of the United States, Department of Audio-Visual Instruction, 1960. 724 p.

Lange, P. C. (ed.) *Programmed instruction. 66th yearbook of the National Society for the Study of Education.* Chicago, National Society for the Study of Education, 1967. 337 p.

Collection of articles by leading workers in the field of PI. Written for an audience of educators in general, rather than for other PI specialists.

Leith, G. O. M. *Second thoughts on programmed learning: developments in the ideas and applications of programming, including computer based learning.* National Council for Educational Technology, 1969. 16 p. (Occasional Paper No. 1.)

LEITH, G. O. M., *et al. A handbook of programmed learning*. 2nd ed. Birmingham, University of Birmingham, 1966. 120 p.

A general introduction, including psychological background and an extensive annotated bibliography.

PSYCHOLOGY AND PROGRAMMED INSTRUCTION

AUSUBEL, D. P. *Educational psychology, a cognitive view*. New York, Holt, Rinehart & Winston, 1968. 685 p.

An educational psychology textbook, concentrating specifically on the problems of learning and adopting frequently a theoretical position divergent from Skinner's. Especially useful as background for users and producers of programmes at secondary and higher levels, and for those constructing curricula, or preparing long self-instruction courses.

GAGNÉ, R. M. *The conditions of learning*. New York, Holt, Rinehart & Winston, 1965.

The author isolates distinct stages in the process of learning and suggests teaching strategies appropriate to each stage. While not dealing specifically with programmed instruction, the book provides a stimulating perspective on the structuring of teaching in general, as well as specific ideas of use to the producer of a self-instructional programme.

GLASER, R.; TABER, J.; SCHAEFFER, H. *Learning and programmed instruction*. Reading, Mass., Addison-Wesley, 1965. 185 p.

In a relatively small volume, the authors review a number of the more important techniques in writing a programmed text, and discuss their psychological basis. Of more limited scope than other books in this section, it is also more directly applicable.

SKINNER, B. F. *The technology of teaching*. New York, Appleton-Century-Crofts, 1968. 271 p.

For many, the best-known application of Skinner's theories is the linear programmed text. In this book, Skinner discusses other ways of teaching and other aspects of education, and applies his theories to them. Operant conditioning emerges as much more than a matter of putting blanks in short sentences.

PROGRAMMING TECHNIQUES

BRETHOWER, D. M.; MARKLE, D. G.; RUMMLER, G. A.; SCHRADER, A.W.; SMITH, D. E. P. *Programmed learning, a practicum*. Ann Arbor, Mich., Ann Arbor Publishers, 1965. 247 p.

A programmed manual most directly applicable to the development of learning materials for vocational training. However, it also demonstrates a number of universally useful techniques and contains many stimulating ideas and interesting examples of teaching sequences.

ESPICH, J. E.; WILLIAMS, B. *Developing programmed instruction materials*. Palo Alto, Fearon, 1967. 138 p.

A short and simple practical guide, presenting a good variety of techniques and concentrating especially on topics in the fields of technical education and vocational training.

MAGER, R. F. *Preparing instructional objectives*. Palo Alto, Fearon, 1962. 62 p.

A readable programmed text discussing practical details of setting objectives, an activity essential to most programme construction and one which increasingly forms a part of curriculum development in general.

MARKLE, S. M. *Good frames and bad*. 2nd ed. New York, J. Wiley, 1969. 308 p.

A programmed text discussing programming styles and techniques, together with their theoretical background, and teaching the reader to avoid or correct common errors in writing a programme. Especially valuable for those teaching conceptual subject-matter.

ROWNTREE, D. *Basically branching, a handbook for programmers*. London, Macdonald, 1966. 209 p.

A straightforward discussion of techniques especially applicable to the writing of programmed texts at secondary school or junior college level. Based on the author's experience in producing 'branching' programmes.

PSYCHOLOGICAL

S.C.E.R.T., West Bengal
Library
Calcutta
25/3, B. C. Ro

Form No. 3.

PSY, RES.L-1

Bureau of Educational & Psychological Research Library.

The book is to be returned within the date stamped last.

....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

WBGP-59/60-5119C-5M

Form No. 4

BOOK CARD

Coll. No.............. Accn. No. 2832

Author..............................

Title...............................

Date.	Issued to	Returned on
....	....	....

371.3
UNE

U.S.
Plus
[A.2769]

Price Rs.
Orient Longma